Partnerships for Science Education

Project Number: 101006468
Project Acronym: PAFSE
Project title: Partnerships for ScienceEducation

D2.5 DIGITAL EDUCATIONAL RESOURCES AND LEARNING OBJECTS AND EDUCATIONAL SCENARIOS

(FINAL VERSIONS)

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Contents

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List of abbreviations

AMU	Adam Mickiewicz University
CTI	Computer Technology Institute and Press “Diophantus”
INESC-TEC	Institute for Systems and Computer Engineering, Technology and Science
ISEL	Instituto Superior de Engenharia de Lisboa
KPI	Key Performance Indicator
PAFSE	Partnerships for Science Education
PRP	Portuguese Road Safety Association
STEM	Science, Technology, Engineering, Mathematics
UOI	University of Ioannina
UCY	University of Cyprus
UMINHO	University of Minho
UNL	NOVA University of Lisbon
WP	Work Package

1. Document history and co-authorship

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 101006468.

This document is ***Deliverable 2.5 Digital educational resources and learning objects and educational scenarios (final versions)*** to be submitted in month 24.

Version	Date	Released by	Notes
1.0	31.08.2023	Costas Constantinou (UCY), Andreani Baytelman (UCY), Elena Siakidou (UCY)	First version

2. Educational Scenarios (updated versions) per partner

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2.1. University of Cyprus (UCY)[1]

AMENDMENTS

Amendments of the revised version of the educational scenario entitled: "*Healthy Eating and Childhood Obesity: Challenges and Solutions*"

- Indication of certain points, activities, or resources of the scenario as optional, in order to have shorter duration.
- Addition of more explanatory notes concerning classroom organization and jigsaw learning technique, aiming to support teachers to manage teaching time more effectively and engage all students in the learning process.
- Addition of prerequisite knowledge and skills
- Content optimization in order to enhance accuracy, clarity and quality of the scenario content.
- Format and language improvement of a scenario, ensuring greater clarity and cohesiveness throughout the document.
- Addition of explanatory notes on the involvement of external partners relevant to this specific scenario and proposition of specific actions.

Amendments of the revised version of the educational scenario entitled: "*Vaccines development and the science response to hesitancy hesitancy*"

- Indication of certain points, activities, or resources of the scenario as optional, in order to have shorter duration.
- Addition of more explanatory notes concerning classroom organization and jigsaw learning technique, aiming to support teachers to manage teaching time more effectively and engage all students in the learning process.
- Addition of prerequisite knowledge and skills
- Content optimization in order to enhance accuracy, clarity and quality of the scenario content.
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- Addition of explanatory notes on the involvement of external partners relevant to this specific scenario and proposition of specific actions.

Amendments of the revised version of the educational scenario entitled: *Biological, social, cultural and economic dimensions of tobacco smoking*

[1] UCY had developed 5 educational scenarios. UCY proceed with 3 educational scenarios (min. requirement), since no interest was expressed by teachers for the other 2 scenarios. Thus, 2 of 5 educational scenarios were not tested/implemented and there no amendments made.

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- Insert an additional primary research question for school project: *What are the main reasons that people in the local community where you live give for tobacco smoking of students at your school?*
- Insert a short text concerning history of tobacco smoking
- Indication of certain points, activities, or resources of the scenario as optional, in order to have shorter duration.
- Addition of more explanatory notes concerning classroom organization and jigsaw learning technique, aiming to support teachers to manage teaching time more effectively and engage all students in the learning process.
- Addition of prerequisite knowledge and skills
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2.1.1. Healthy Eating and Childhood Obesity: Challenges and Solutions

Main partner responsible
University of Cyprus, Nicosia, Cyprus

Element of the scenario
Subject: Biology classes (contribution by IT teachers and/or Home economics, English, Art teachers, etc.)
Grade: 8th grade (+/- 13-14 years old students)
Estimated duration: 8 lessons X 40 min and Open Schooling Event

- 4 lessons (lesson 1 – lesson 4) of 40-45 minutes for the promotion of conceptual and epistemic understanding related to PAFSE topic: *Looking after myself and others- Healthy Eating*.
- 4 lessons / sessions of 40-45 minutes for school project (lesson/session 5 – session 8)
- Open Schooling Event.

Classroom organization requirements
Lesson 1- Lesson 4: Students' groups of 4-5 students (collaborative learning), individual work (individual reflection on one's own learning), whole-class (whole-class discussions).
Lesson 5- Lesson 8: Students' groups of 4-5 students, cooperative learning method, use of jigsaw technique, whole-class (whole-class discussions).

PAFSE Topic: This Educational Scenario is an integrated learning module in Public Health Education related to the PAFSE 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.

Title of educational scenario: *Childhood Obesity: Challenges and Solutions*

Prerequisite knowledge and skills

- Basic conceptual understanding concerning food and living organisms
- Basic knowledge of software and browsers
- Basic skills of group work and collaborative learning

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 PAFSE topic *Healthy Eating*:
Socioscientific topic: *Childhood Obesity: Challenges and Solutions*
8th Grade students, often, share their opinions, habits and experiences on health and nutrition issues on

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a google blog, which is often visited by their friends and classmates. Last week four 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 factor leading to 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 factors leading to 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.*

Your mission is to investigate the following primary research questions:

- *What are the causes, health risks and solutions related to childhood obesity?*
- *What are 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 (lesson 1-lesson 4).
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 (lesson 5-lesson 8).
Additionally, students organising and holding an Open Schooling Event for a discussion about childhood obesity and proposing solutions will act as knowledgeable social agents through citizenship education.

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.

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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.

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.

Inorganic 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.

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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).
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.

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,

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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)

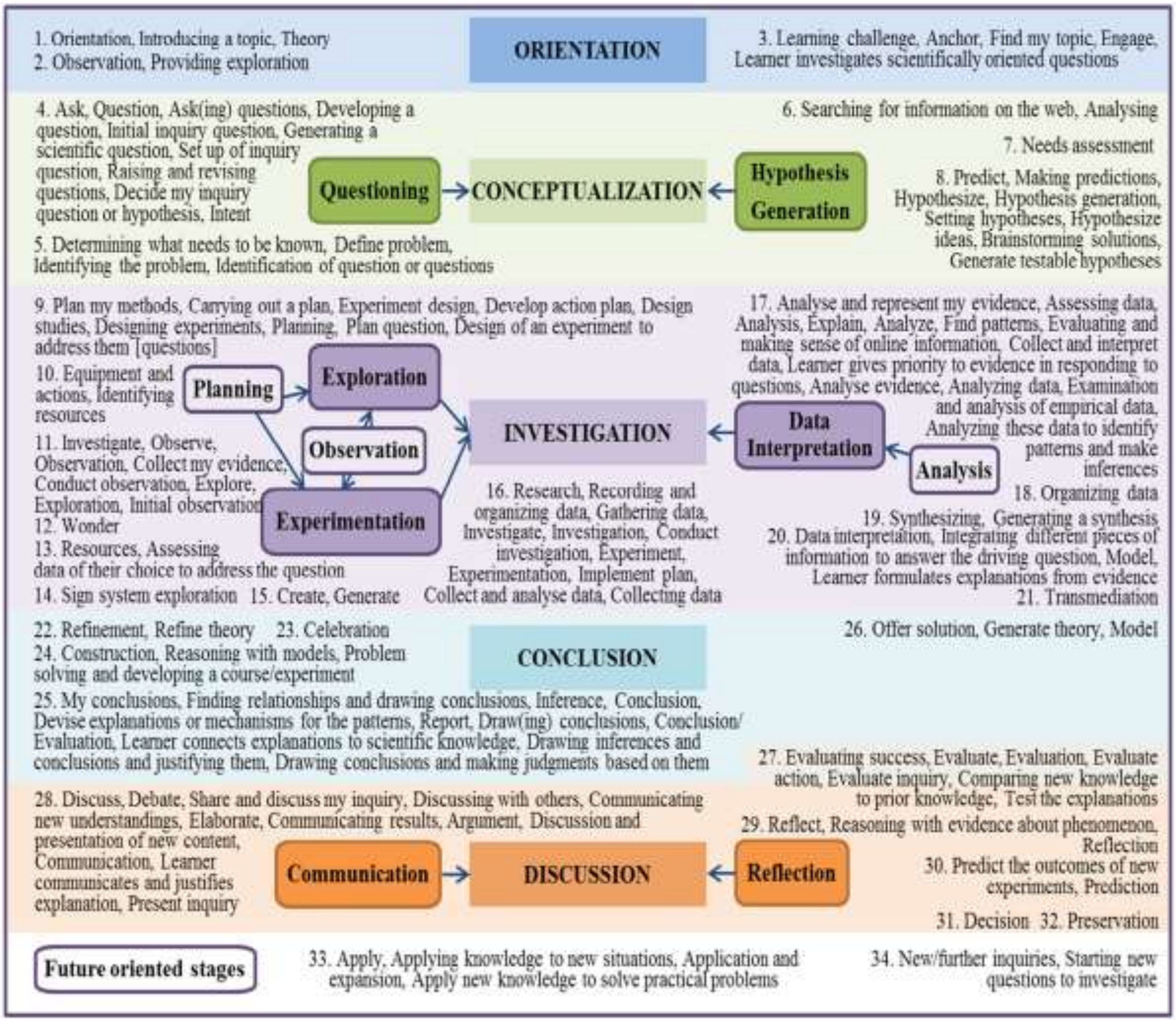

Fig. 1. The main inquiry phases sub-phases are described below (Pedaste et al., 2015).

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). Collaborative learning can boost the learning outcomes, students' interests and participation and their collaboration and communication skills.

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.

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One type of cooperative learning method is the **jigsaw technique.** The jigsaw technique is a method of organizing classroom activity that makes students dependent on each other to succeed. It breaks classes into groups that each assemble a piece of an assignment and synthesize their work when finished. The process derives its name from the jigsaw puzzle because it involves putting the parts of the assignment together to form a whole picture.

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 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-

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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.

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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Content

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.

Competences / Learning Goals

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.

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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)

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

Childhood 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
- Lessons 5, 6, & 7 (120 min): Primary research questions of School project (a) causes, health risks and solutions related to childhood obesity, (b) individual and governments' responsibility for reducing childhood obesity, (c) Community’s perceptions and knowledge concerning childhood obesity?
- Lesson 8 (40 min): Artefacts of School project: Designing and presenting a poster and leaflet on the topic *Childhood Obesity: Challenges and Solutions*

Organizing an Open Schooling Event (a forum with students, teachers, parents, social partners of the local community) on the socioscientific topic: *Childhood Obesity: Challenges and Solutions*

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

Lesson 1 (40 min):

1. Awaken interest into the subject – Introducing a related socioscientific issue

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

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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 knowledge
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
5. explain the importance of proteins, lipids, vitamins and nucleic acids to human functioning
6. distinguish clearly between organic and inorganic 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) – school project:
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?
- What are the community's perceptions and knowledge concerning 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

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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
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 scientific poster with the research questions of this unit, the methodology, the results, and the conclusions of the investigation related to the socioscientific topic: *Childhood Obesity: Challenges and Solutions*
2. organise an Open Schooling Event for research presentation and discussion (students, teachers, parents, social partners of the local community) on the topic: *Childhood Obesity: Challenges and Solutions*
3. create a public health brochure promoting healthy eating
4. improve critical thinking skills and communication and collaboration skills

Open Schooling Event
During Open Schooling Event, students should be able to…
1. Introduce their research project
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
<u>Course of the Lesson 1:</u>
Plenary (whole-class)
The lesson starts with a multimedia-show related to healthy and unhealthy eating. After the multimedia-show, 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, etc.?
After short discussion and reflection, the teacher can introduce the socioscientific topic entitled *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:

Group work (4-5 students)

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 a specific Worksheets and DLOs (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 students are asked to start working on a specific Worksheet and DLO (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 a specific worksheet, the teacher gives feedback to the plenary of the class (whole class).

Course of the Lesson 4:

Group work (4-5 students)

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 their 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 a specific Worksheet answering open-ended questions. (OPTIONAL ACTIVITY)

Students work in group (4-5 students) cooperatively and the teacher moves around the classroom asking reflective and supportive questions and giving feedback. When the students finish activities of a worksheet, 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

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related to childhood obesity.

<u>School Project</u>
<u>Course of the Lessons 5, 6 & 7:</u>
Students are organized in 4 groups of 4-5 students - Use of jigsaw technique.
Steps 1-6:
1. The teacher starts the lesson presenting again the Socioscientific topic *Childhood Obesity: Challenges and Solutions* and the primary research questions:

- What are the causes, health risks and solutions related to childhood obesity?
- What are 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. Additionally, the teacher explains and promotes the jigsaw technique, breaking class into four groups that each assemble a piece of an assignment and synthesize their work when finished.
3. To answer the research questions *What are the causes, health risks and solutions related to childhood obesity?* Students of first group (Group 1) 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 research questions related to childhood obesity. For this task students are provided with extra appropriate material as homework.
Then, students are asked to use a specific Worksheet 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.
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.
4. Students of second group (Group 2), are asked to construct a prediction model of childhood obesity. The teacher can ask *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) to design a prediction model for childhood obesity as homework. Teacher will evaluate the students' models and give feedback in the next lesson. (OPTIONAL ACTIVITY).
5. To answer the research question *what is individuals' and governments' responsibility for reducing childhood obesity?* Students of third group (Group 3) 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 research questions related to childhood obesity. For this task students are provided with extra material as homework.

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Then, students are asked to use a specific Worksheet 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.
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.
Then, students are asked to summarize their conclusions on individuals' and governments' responsibility for reducing childhood obesity and using a worksheet.
6. To answer the research question "*What are the community's perceptions and knowledge concerning childhood obesity?",* students of fourth group (Group 4) are asked to design a questionnaire to collect data and analyze them to draw conclusions. Teacher explains the way of Questionnaire preparation using Google form. The cooperation of IT teachers could be important in this step.

<u>Course of the Lesson 8:</u>
Students are organized in 4 groups of 4-5 students - Use of jigsaw technique.
Steps 1-5:
1. The teacher starts the lesson with evaluation and feedback on students' work related to the primary questions of the socio-scientific issue*:Childhood Obesity: Challenges and Solutions.*
2. 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? 6 Students of all group are asked to prepare a scientific poster.
3. 6 Students of all groups are asked to prepare a brochure related to healthy eating and Obesity. Teacher will evaluate the students' leaflet and give feedback in the next lesson.
4. When appropriate, teacher directs discussion towards designing, organizing, and holding an Open Schooling Event (a forum with students, teachers, parents) on the topic: *Childhood Obesity: Challenges and Solutions.* How do we plan, organize, hold, moderate, and facilitate more effective Open Schooling Events? What is our vision? What do we expect to accomplish at this event?
5. After a short discussion, 6-10 students of all groups are asked to prepare an invitation, the agenda for the Open Schooling Event, and a public health brochure promoting healthy eating, in order to distribute it to the participants. Additionally, they are asked to organize the Open Schooling Event.
Holding an Open Schooling Event on the socioscientific topic: *Childhood Obesity: Challenges and Solutions, a*fter consultation with the school.

<u>Assessment methods</u>
(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)

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3. Development of a predictive model of childhood obesity
4. Creation and Presentation of a scientific poster on the topic: *Childhood Obesity: Challenges and Solutions.*
5. Organizing and holding an Open Schooling Event (a forum with students, teachers, parents, social partners of the local community) on the topic*: Childhood Obesity: Challenges and Solutions.*
6. Create a public health brochure promoting healthy eating (Formative and summative assessment).
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 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

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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.*
4. Specific information for holding an Open Schooling Event (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 Pafse topic: Looking after myself and others – Healthy Eating

Topics

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

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Research management, design and administration

Primary 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:

Students are organized in four groups of 4-5 students -Use of jigsaw technique.

Session 1

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 4-5 students - Use of jigsaw technique.

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

An expert (e.g.. a nutritionist or paediatrician) 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 and reflect about. Additionally, students of first group (Group 1) will write a short report concerning causes, health risks and possible solutions related to childhood obesity.

Students of second group (Group 2) will draw a prediction model for childhood obesity, using data of the Ministry of Health and a specific Model coding sheet. The cooperation of IT teachers or mathematicians could be important in this step.

1. 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 discussion with the expert, students of third group (Group 3) are urged to write a short report concerning individuals' and governments' responsibility for reducing childhood obesity at home (homework).

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2. 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. Group four (Group 4) is responsible for designing a 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. The cooperation of IT teachers or mathematicians could be important for this step.

Session 3

1. 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.

2. Challenge: Creating a scientific poster in power point, writing Introduction, Methodology, Results, Conclusions and Discussion.

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

Development process:

The project is based on guided research about Healthy Eating and Childhood Obesity The four lessons (lesson 5-lesson 8) will be supervised by the teachers and developed by the students, with scheduled moments for checking the work development.

Visits to organizations interested in STEM and public health education could be organized. Additionally, a conference with STEM professionals could be organized. 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, scientists working on urban and environmental health, researchers of PAFSE consortium, etc.

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

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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 brochure) 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. Additionally, 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 scientific poster, health brochure 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 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.*

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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 nucleic 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 teeth. 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.

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	Question 2.8 What nutrients are very important for bones and teeth? A) Minerals B) Carbohydrates C) Lipids.
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.

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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.
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.

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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.
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	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

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prevent health threats.	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. 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.

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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

2.1.2. Vaccines development and the science that responds to hesitancy

Main partner responsible
University of Cyprus, Nicosia, Cyprus

Element of the scenario
Subject: Biology classes (contribution from IT teachers and/or Home economics, English, Art teachers etc.)
Grade: 9th grade (+/- 14-15 years old students)
Estimated duration: 9 lessons X 40 min

- 5 lessons (lesson 1 – lesson 5) of 40-45 minutes for the promotion of conceptual and epistemic understanding related to PAFSE topic: *Looking out for my community: Vaccines development and the science that responds to hesitancy*
- 4 lessons / sessions of 40-45 minutes for school project (lesson/session 6 – session 9)
- Open Schooling Event.

Classroom organization requirements

- Lesson 1- Lesson 5: Students' groups of 4-5 students (collaborative learning), individual work (individual reflection on one's own learning), whole-class (whole-class discussions).
- Lesson 6- Lesson 9: Students' groups of 4-5 students, cooperative learning method, use of jigsaw technique, whole-class (whole-class discussions).

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

Prerequisite knowledge and skills

- Basic conceptual understanding concerning microbes and diseases
- Basic knowledge of software and browsers
- Basic skills of group work and collaborative learning

Overview
The main goal of this unit is to promote students' understanding on the relationships between microbes and infectious diseases, the human defence mechanisms against pathogens, vaccines development and

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how science responds to vaccine hesitancy, promoting high-order thinking skills, communication and collaboration skills and critical health literacy.

A specific socioscientific topic related to vaccines and vaccinations provides the scenario for the inquiry-based primary questions of this unit related to the learning PAFSE topic: Looking out for my community: Vaccines development and the science that responds to hesitancy.

Socioscientific topic:
Microbes, Vaccines development and hesitancy
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 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 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.

Your mission is to investigate the following primary research questions:

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

First, students will obtain a basic conceptual understanding about microbes, infectious diseases, the human defence mechanisms against pathogens, the impact that infectious diseases had and still have on societies and public health, how to prevent infections by using vaccines, as well as vaccines development. 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, construct arguments, make inferences, synthesize and draw conclusions.
Additionally, students organising and holding an Open Schooling Event with a public debate (students, teachers, parents, social partners of the local community) on the topic: Microbes, Vaccines and Vaccine *hesitancy,* will act as knowledgeable social agents through citizenship education.

Content glossary

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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.

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)

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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.

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). Collaborative learning can boost the learning outcomes, students' interests and participation and their collaboration and communication skills.

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.

One type of cooperative learning method is the jigsaw technique. The jigsaw technique is a method of organizing classroom activity that makes students dependent on each other to succeed. It breaks classes into groups that each assemble a piece of an assignment and synthesize their work when finished. The process derives its name from the jigsaw puzzle because it involves putting the parts of the assignment together to form a whole picture.

c. Argumentation-Based Science Teaching Approach

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.

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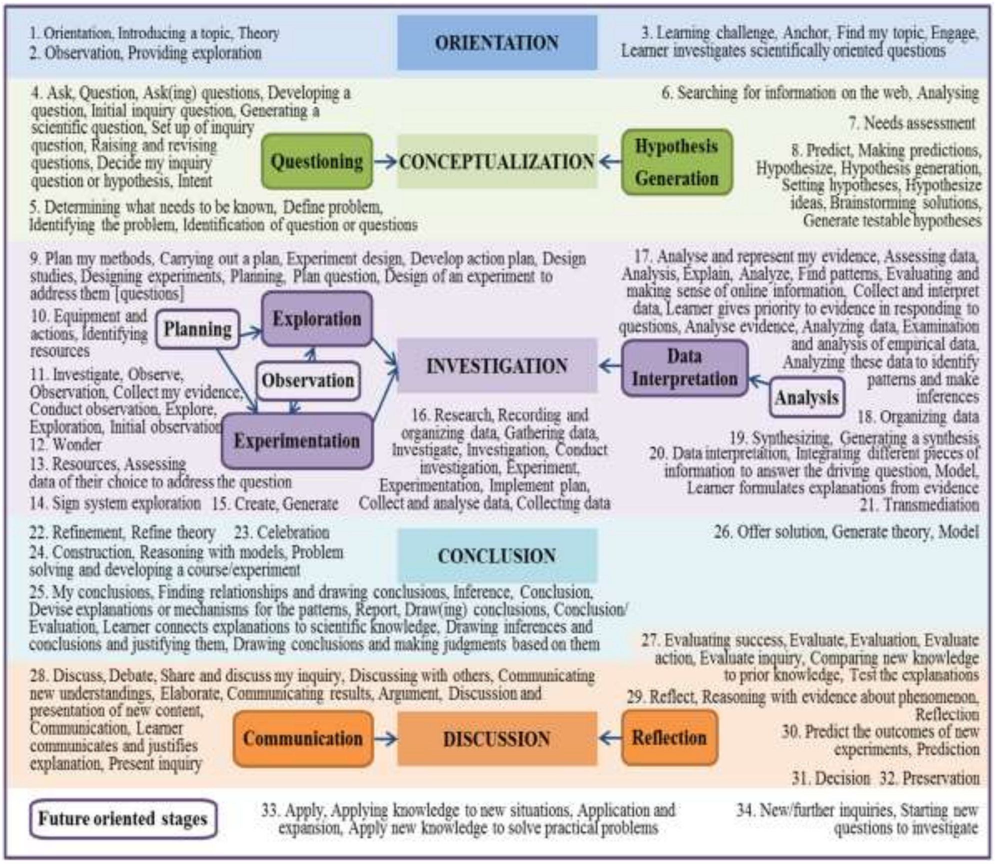
ii. For exploring these questions, social and scientific inquiry is used (e.g., planning, searching and evaluating information - using a variety of evidence sources, such as research, expert knowledge, practice experience and data to capture the complexity of a problem, analysing, negotiating the social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



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

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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 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-

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transmitted diseases and antibiotic-resistant bacteria strains are common issues of the One Health approach.

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Content
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).

Competences / Learning Goals
Knowledge (Core Concepts)
1. Transdisciplinary concepts: Critical health literacy, STSE (Science, Technology, Society, Environment)

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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 other 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.

<u>Title of whole module and titles of individual lessons</u>
Title of whole module
Microbes, Vaccines development and hesitancy

Titles of individual lessons
- 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 & 8 (120 min): Primary research questions of School project (a) How do vaccines influence the progress of an epidemic and a pandemic? (b) Should a low efficacy vaccine be released to the public? (c) What are the community’s perceptions and knowledge concerning immunity and vaccination?
- Lesson 9 (40 min): Artefacts of School project: Designing and presenting research results and a leaflet related to vaccines and vaccinations, as well as a public debate on the topic: Vaccines development and hesitancy.

Organizing an Open Schooling Event (a forum with students, teachers, parents, social partners of the local community) on the topic *Microbes, Vaccines development and hesitancy* and conducting a public debate on the topic: Microbes, *Vaccines development and hesitancy.*

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Learning goals and objectives

Lesson 1 (40 min):
1. Awaken interest into the subject - Introducing a related socioscientific issue
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: *Microbes, Vaccines development and hesitancy*
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
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

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Lessons 6, 7 & 8 (120 min) –School Project

At the end of lessons 6, 7 & 8 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? (Debate)*
   - *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 and evaluate 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
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 9 (40 min):

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

1. 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?*
2. prepare and organise a public debate (students, teachers, parents, social partners of the local community) on the socio-scientific issue question: *Should a low efficacy vaccine be released to the public?*
3. improve communication and collaboration skills.
4. develop responsible citizenship and critical health literacy.

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.

<u>**Didactical methods and activities**</u>

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Course of the Lesson 1:
Plenary (whole-class)
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 *Microbes, Vaccines development and hesitancy* 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.

Course of the Lessons 2 & 3:
Work on groups of 4-5 students
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 specific Worksheets and a DLOs with True and False activity as well as 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 (4-5 students) cooperatively and teacher moves around the classroom asking reflective and supportive questions and giving feedback. When the students complete activities of a worksheet, 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 a specific 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 students complete activities of a worksheet, the teacher gives feedback to the plenary of the class. (OPTIONAL ACTIVITY)
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 a specific Worksheet. (OPTIONAL 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 complete

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activities of a specific worksheet, 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 and a DLO 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 a specific Worksheet and DLO 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 a specific Worksheet 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.
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 a specific Worksheet and DLO.
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 a specific Worksheet and a DLO 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 a specific worksheet, the teacher gives feedback to the plenary of the class.
The lesson ends with a DSO related to vaccination and herd immunity and the 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.

School Project

Course of the Lessons 6, 7 & 8

Work on groups of 4-5 students – Use of jigsaw technique
Steps 1-5:
1. The teacher starts the lesson presenting again the Socioscientific topic *Microbes, vaccines development and hesitancy*, and the primary research questions of this unit:

- 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. Then, teacher moderates a discussion on planning, searching and evaluating information about vaccines, analysing, making inferences, synthesising and drawing conclusions, constructing arguments

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from evidence in order to manage the research questions of a socioscientific topic. Additionally, the teacher explains and promotes the jigsaw technique, breaking class into four groups that each assemble a piece of an assignment and synthesize their work when finished.
3. To answer the research questions *How do vaccines influence the progress of an epidemic and a pandemic?*, Students of first group (Group 1) 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 vaccines, epidemics and pandemics. For this task students are provided with extra appropriate material as homework.
4. To manage the question, *should a low efficacy vaccine be released to the public?* Students of second and third group (Groups 2 and 3) 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 a specific worksheet for organizing and evaluating information, analysing, construction of arguments, counterarguments and rebuttals, making inferences, synthesising and drawing conclusions in order to make decision on the 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.
Additionally, students are asked to construct criteria and create a template that can be used for arguments 'evaluation and improving arguments/ counterarguments/ rebuttals**.** The criteria and the arguments will be presented and evaluated in the plenary of a class.
5. To answer the research question *What are the community's perceptions and knowledge concerning immunity and vaccination?*, students of fourth group (Group 4) are asked to design a questionnaire to collect data and analyze them to draw conclusions. Teacher explains the way of Questionnaire preparation using Google form and gives some examples. The cooperation with IT teachers could be important in this step.

<u>Course of the Lesson 9</u>
Plenary (whole-class)
Steps 1-5
1.The teacher starts the lesson with evaluation and feedback on students' work related to the primary questions of the socio-scientific issue: *Microbes, vaccines development and hesitancy*
2. When appropriate, teacher directs discussion towards organizing and conducting a public debate on the topic: *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.

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- ✓ 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.
3. When appropriate, teacher directs discussion towards present (ppt presentation) the research questions of this unit, the methodology, the results, and the conclusions of the investigation related to the socioscientific issue related to microbes and vaccines.? 6-8 Students of all group are asked to prepare a scientific presentation.
4. 8 Students of all group are asked to organize a public debate on the topic: Should a low efficacy vaccine be released to the public?
5. 6-8 students of all groups are asked to prepare an invitation, the agenda for the Open Schooling Event, and a public health brochure concerning vaccinations and public health, in order to distribute it to the participants. Additionally, they are asked to organize the Open Schooling Event.
Holding an open schooling event and presenting results of research questions and a public debate on the topic: *Health and Vaccines: Should a low efficacy vaccine be released to the public?* after consultation with the school.

Assessment methods
(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 of the results of the research questions on the PAFSE topic: *Vaccines development and*

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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. Educational short video related to the Spanish flu 1918 in Cyprus: https://youtu.be/U0i_zqn6_Fs
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. Interactive 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).
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. Specific 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).
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 vaccination and herd immunity.
Supplementary Educational Resources (SERs)
1. Short educational video related to Human Defence Systems against Pathogens at: https://youtu.be/aq-F4rNuj3Y

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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. Specific Worksheets (see the attached relevant teaching and learning activities)

Lessons 6, 7 & 8

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

Lesson 9

Supplementary Educational Resources (SERs)

1. Specific information for planning, organizing and conducting a public debate.
2. Specific information for holding an open schooling event

<u>Digital educational resources</u>

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
https://eur-lex.europa.eu/legal-content/EL/TXT/HTML/?uri=CELEX:52018DC0245&from=EN (Vaccine hesitancy in European Union).

<u>School Research Project</u>

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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:
Students are organized in four groups of 4-5 students – Use of jigsaw technique.

Session 1
Students are organized in groups of 4-5 students - Use of jigsaw technique.
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 - Use of jigsaw technique.

1. Challenge: Investigating how vaccines influence the progress of an epidemic and a pandemic (Group 1)
An expert (Epidemiologist, Public health specialist, etc.) 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

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concerning the vaccines' influence on the progress of an epidemic and a pandemic, as well as how science responds to hesitancy (nature of science).

2. Challenge: Argumentation and decision making concerning the socio-scientific dilemma: *Should a low efficacy vaccine be released to the public?* (Group 2 and 3)
Students discuss in their group towards a construction 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?* Students are asked to Support their claims, using as many as possible justifications supported by evidence, 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.

3.Challenge: Creating a template that can be used for arguments' evaluation and improving arguments, counterarguments and rebuttals
Students work in their groups constructing criteria and creating a template that can be used for arguments' evaluation and improving arguments/ counterarguments/ counter-counterarguments (Group 2 and 3).

4. Challenge: Designing a questionnaire (social research tool) to investigate the community's perceptions and knowledge concerning immunity and vaccination. (Group 4)
Teacher explains the fundamental principles of question selection and formulation, when designing a questionnaire and presents some examples. 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 group of 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. The cooperation of IT teachers or mathematicians could be important in this step.

<u>Session 3</u>
Students are organized in groups of 4-5 students - Use of jigsaw technique.

1. Challenge: Creating a rubric for evaluation of public debate (Group 2 and 3)
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.

2.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. (Group 4)

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3.Challenge: Preparing a presentation with the research results and creating an informative flyer (brochure) explaining the role of vaccinations for public health. (Group 1)
Students are provided with appropriate guidance in order to design an informative flyer (brochure) explaining the role of vaccinations for public health. (homework). Teacher will evaluate the students' brochure and give feedback in the next lesson.

Session 4

Students are organized in groups of 4-5 students - Use of jigsaw technique.

1.Challenge: Preparing a public debate and the post-debate discussion for open schooling event. (Group 2and 3)
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.

2.Challenge: Preparing an invitation and an agenda for the open schooling event on the socioscientific topic: *Microbes and Vaccines development and hesitancy.* Creating a brochure concerning vaccinations and public health. (Group 1 and 4)
All groups (Groups 1-4), organizing an Open Schooling Event on the socioscientific topic: Microbes and Vaccines development and hesitancy, after consultation with the school.

Development process:
The project is based on guided research about the PAFSE topic *Vaccines development and the science that responds to hesitancy*. The four lessons (lesson 6-lesson 9) will be supervised by the teachers and developed by the students, with scheduled moments for checking the work development.
Visits to organizations interested in STEM and public health education could be organized. Additionally, a conference with STEM professionals could be organized. 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, scientists working on urban and environmental health, researchers of PAFSE consortium, etc.

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

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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. 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 brochure 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).

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

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

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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

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	organisms that, under the right conditions, can multiply exponentially, on average once every 20 minutes. **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

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	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 , **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

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	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.
5. Feels able to influence the prevention of infections by others	**Question 5.1** I feel able to influence the prevention of infections by others (family, friends). 1) Definitely true... 5) definitively false.

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(e.g., family, peers, friends).	**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.

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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.
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

2.1.3. Biological, social, cultural and economic dimensions of tobacco smoking

Main partner responsible
University of Cyprus, Nicosia, Cyprus

Element of the scenario
Subject: Biology (contribution from IT teachers and/or Home economics, English, Art teachers etc.)

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<u>Grade</u>: 9th grade (+/- 14-15 years old students)
<u>Estimated duration</u>: 9 lessons X 40 min and Open Schooling Event

- 5 lessons (lesson 1 – 5 lesson 4) of 40-45 minutes for the promotion of conceptual and epistemic understanding related to PAFSE topic: Looking after myself and others - Substance Tobacco"
- 4 lessons / sessions of 40-45 minutes for school project (lesson/session 6 – session 9)
- Open Schooling Event**.**

<u>Classroom organization requirements</u>
Lesson 1- Lesson 5: Students' groups of 4-5 students (collaborative learning), individual work (individual reflection on one's own learning), whole-class (whole-class discussions).
Lesson 6- Lesson 9: Students' groups of 4-5 students, cooperative learning method, use of jigsaw technique, whole-class (whole-class discussions).

<u>PAFSE Topic</u>: This Educational Scenario is an integrated learning unit in Public Health Education related to the PAFSE topic: *Looking after myself and others. Substance: Tobacco*
<u>Educational Scenario Title</u>: *Biological, social cultural and economic dimensions of tobacco smoking*

<u>Prerequisite knowledge and skills</u>

- Basic conceptual understanding concerning human respiratory system
- Basic knowledge of software and browsers
- Basic skills of group work and collaborative learning

<u>Overview</u>
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: Substance Tobacco*.

Socioscientific topic:
Biological, social cultural and economic dimensions of tobacco smoking
Tobacco has been growing wild in the Americas for nearly 8000 years. Around 2,000 years ago tobacco began to be chewed and smoked during cultural or religious ceremonies and events. The first European to discover smoking was Christopher Columbus. In 1531 tobacco was cultivated for the first time in Europe. By 1600 tobacco use had spread across Europe and by the 1700s smoking had become more widespread

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and a tobacco industry had developed.
Cigarette making machines were developed in the latter half of the 1800s. The first such machines produced about 200 cigarettes per minute (today's machines produce about 9,000 per minute). Cheap mass production and the use of cigarette advertising allowed tobacco companies to expand their markets during this period. The prevalence of cigarette smoking continued to grow in the early 20th Century.
Smoking increased dramatically during the world wars, mainly due to the policy of providing free cigarettes to allied troops as a 'morale boosting' exercise. Later in the twentieth century, smoking became less popular. 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.
On the other hand, 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, many people begin smoking as teenagers and do not give up smoking even when knowing the biological hazards. Various scientists argue that tobacco use is associated with biological, social, cultural and economic factors.
In recent months, it has been observed that many students in your school smoke a lot, even though they are aware of the biological effects of smoking. Parents and teachers at your school are very concerned about this increase in smoking.

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?*
- *What are the main reasons that people in the local community where you live give for tobacco smoking of students at your school?*

First, students will obtain a basic conceptual understanding about human respiratory system, aerobic and anaerobic respiration. Yet, they will identify the relationship between health and tobacco smoking (lesson 1-lesson 5).
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 (lesson 6-lesson 9)
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.

<u>Content glossary</u>
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

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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.
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).

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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.

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, 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)

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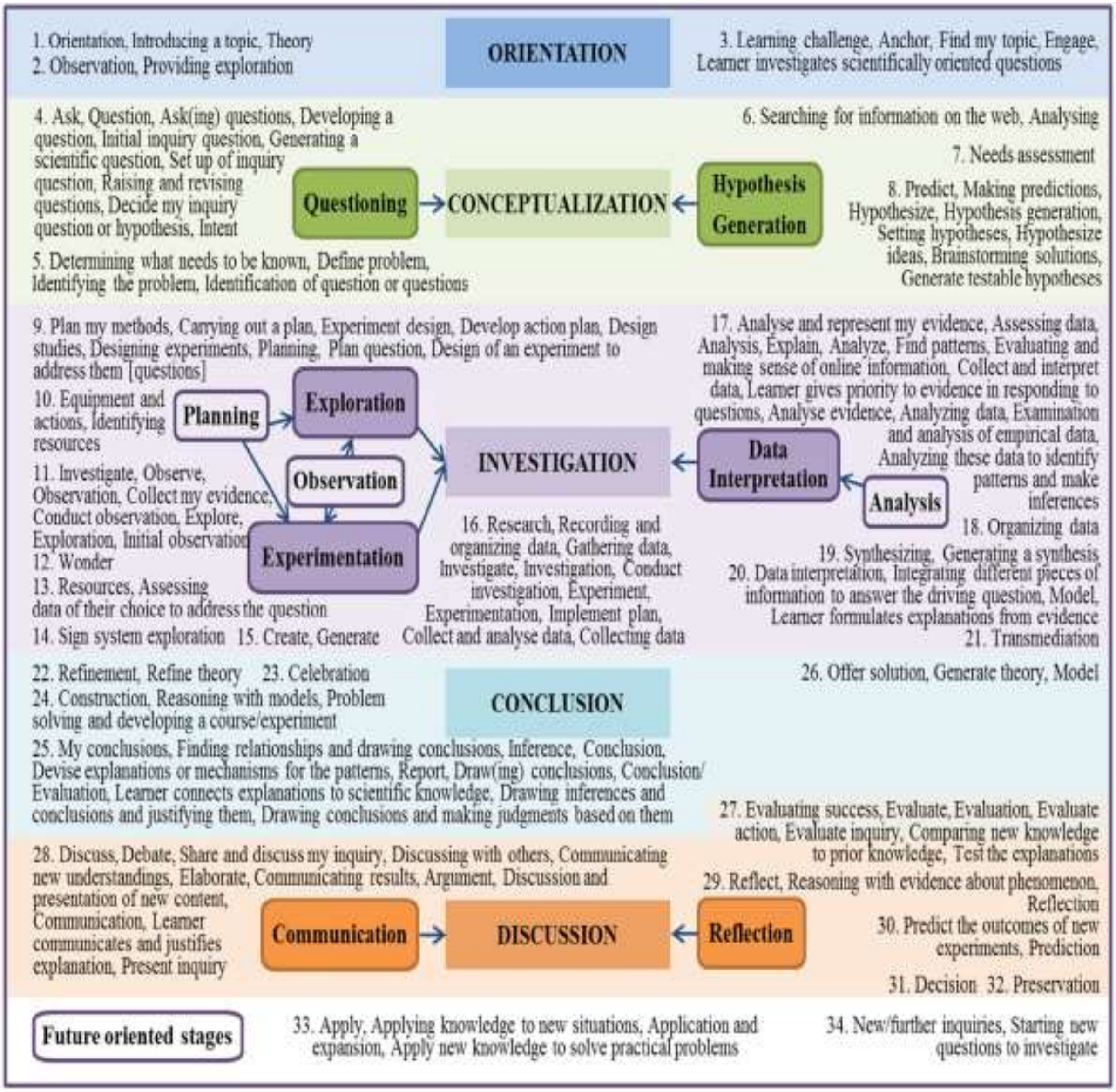

Fig. 1. The main inquiry phases sub-phases are described below (Pedaste et al., 2015).

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). Collaborative learning can boost the learning outcomes, students' interests and participation and their collaboration and communication skills.

One type of cooperative learning method is the jigsaw technique. The jigsaw technique is a method of organizing classroom activity that makes students dependent on each other to succeed. It breaks classes into groups that each assemble a piece of an assignment and synthesize their work when finished. The process derives its name from the jigsaw puzzle because it involves putting the parts of the assignment together to form a whole picture.

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

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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. 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

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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.

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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Content
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.

Competences / Learning Goals
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)
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,

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taking in consideration economic, social, ethical, political cultural, emotional and other 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., tobacco 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.

<u>Title of whole module and titles of individual lessons</u>
Title of whole module:
Biological, social, cultural and economic dimensions of tobacco smoking

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 & 8 (120 min): Primary research questions (a) *What are the biological, social, cultural and economic dimensions of tobacco smoking? (b) What are the main reasons 9th grade students in our school give for tobacco smoking? (c) What are the main reasons that people in the local community where you live give for the smoking of students at your school?*
- Lesson 9 (40 min): Artefacts of School project: Design and present a poster on the topic *Biological, social, cultural and economic dimensions of tobacco smoking, and a public health brochure promoting non-smoking.*
  Organizing an Open Schooling Event (a forum with students, teachers, parents, social partners of the local community) on the socioscientific topic: Biological, social, cultural and economic dimensions of tobacco smoking, in

<u>Learning goals and objectives per lesson</u>
Lesson 1 (40 min)
1. Awaken interest into the subject - Introducing a related socioscientific issue
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
4. complete a diagram of the parts of the human respiratory system
5. improve critical thinking
6. improve communication and collaboration skills

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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 & 8 (120 min)
At the end of lessons 6, 7 & 8 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 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?*
   - *What are the main reasons that people in the local community where you live give for the smoking of students at your school?*
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
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

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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 9 (40 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*
2. organise an Open Schooling Event (forum with 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.

Open Schooling Event
During Open Schooling Event, students should be able to…
1. Introduce their research project
2. inform the public about each of the research questions they have addressed in the previous lessons.
3. distribute public health brochures promoting non-smoking.
3. improve communication and collaboration skills.
4. develop responsible citizenship and critical health literacy.
Summative assessment (Scientific knowledge on human Respiratory System, Gas exchange and cellular respiration and public health. Thinking skills and evidence-based reasoning).

<u>**Didactical methods and activities**</u>
<u>**Course of the Lesson 1**</u>
Plenary (whole-class)
The lesson starts with a multimedia-show related to the history of tobacco use. After the multimedia-show, 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.

<u>**Course of the lesson 2**</u>
Work in groups of 4-5 students

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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 a specific Worksheet (Matching activity). Additionally, students use a DLO to study the percentages of gases in inhaled and exhaled air.
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

Work in groups of 4-5 students
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 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 lungs look like? How big are human 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) and DLO in order to construct a model "How do lungs work?" The teacher displays a diagram/model of human 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?* (OPTIONAL ACTIVITY)
How can you evaluate the predictive power of your model? (OPTIONAL ACTIVITY)
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 to use a specific Worksheet 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 related activities, 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 topic related to tobacco smoking and asks them to look for material on the history of tobacco use, and the effects of tobacco smoking on human respiratory system.

Course of the Lesson 5

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Work in groups of 4-5 students
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 activities related to breathing and respiration, cellular respiration, energy release, mitochondria, aerobic and anaerobic respiration (Worksheets). 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 a specific worksheet, the teacher gives feedback to the plenary of the class.

School Project
Course of the Lessons 6, 7 & 8
Students are organized in 4 groups of 4-5 students - Use of jigsaw technique.
Steps 1-7:
1. The teacher starts the lesson presenting again the Socioscientific 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?*
- *What are the main reasons that people in the local community where you live give for the smoking of students at your school?*

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. Additionally, the teacher explains and promotes the jigsaw technique. Breaking class into five groups that each assemble a piece of an assignment and synthesize their work when finished.
3. To answer the first primary research question *What are the biological, social, cultural and economic dimensions of tobacco smoking?* Students of Group 1 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 a specific Worksheet 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?*
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

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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 of Group 2 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. The cooperation of IT teachers could be important in this step.

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.

5. To answer the research question *What are the main reasons that people in the local community where you live give for the smoking of students at your school?* students of Group 4 are asked to design a questionnaire to collect data and analyze them to draw conclusions. Teacher explains the way of Questionnaire preparation using Google form. The cooperation of IT teachers could be important in this step.

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 Lesson 9</u>

Plenary (whole-class)

The teacher starts the lesson with evaluation and feedback on students' work related to the primary questions of the socio-scientific topic*: Biological, social, cultural and economic dimensions of tobacco smoking.*

1. 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 to tobacco smoking. How do we make a scientific poster in PowerPoint? What should be included in a scientific poster? 6-8 Students of all group are asked to prepare a scientific poster.
2. 6-8 Students of all group are asked to create an informative flyer (brochure) promoting non-smoking. Teacher will evaluate the students' flyer and give feedback in the next lesson.
3. When appropriate, teacher directs discussion towards designing, organizing, and holding an Open Schooling Event (a forum with students, teachers, parents) on the topic: *Biological, social, cultural and economic dimensions of tobacco smoking.* How do we plan, organize, hold, moderate, and facilitate more effective Open Schooling Events? What is our vision? What do we expect to accomplish at this event?
4. After a short discussion, 6-10 students of all groups are asked to prepare an invitation, the agenda for the Open Schooling Event, and organize the Open Schooling Event, after consultation with the school.

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Assessment methods

(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?

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https://youtu.be/8NUxvJS-_0k
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 & 8
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. Specific Worksheets
7. Questionnaire

Lesson 9
Supplementary Educational Resources (SERs)
1. Information for creation of scientific poster
2. Information for creation of a public health brochure
3. Specific information for creation of agenda for a forum
4. 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

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https://www.anticancersociety.org.cy/el/page/non-smokers-league
https://youtu.be/H6DrSG_KQjo
https://youtu.be/cL0mP3IfmHE
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?
- What are the main reasons that people in the local community where you live give for the smoking of students at your school?

Methodology/Implementation:
Students are organized in four groups of 4-5 students -Use of jigsaw technique.
Session 1
Students are organized in groups of 4-5 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 4-5 students:
1. Challenge: Investigating biological, social, cultural and economic dimensions of tobacco smoking

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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 of Group 1 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.

2.Challenge: Investigating the main reasons 9th grade students in their 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 of Group 2 are responsible for designing a questionnaire. Some students get the responsibility to write the questionnaire in an online form, which allows to be more easily delivered to its targets. Some students of Group 2 get the responsibility to analyze the answers of the questionnaire. The cooperation of IT teachers or mathematicians could be important for this step.

3.Challenge: Investigating the main reasons that people in the local community where you live give for the smoking of students at their school. Designing of a questionnaire (social research tool) to investigate the above research question.

Students of Group 3 are responsible for designing a questionnaire. Some students get the responsibility to write the questionnaire in an online form, which allows to be more easily delivered to its targets. Some students of Group 3 get the responsibility to analyze the answers of the questionnaire. The cooperation of IT teachers or mathematicians could be important for this step.

Session 3

1. Challenge: Presentation of the results of the questionnaire, related to the main reasons 9th grade students in their school give for tobacco smoking. In the end, build an infographic to summarize the results.
2. Challenge: Presentation of the results of the questionnaire, related to the main reasons that people in the local community where you live give for the smoking of students at their school. In the end, build an infographic to summarize the results.

3. Challenge: Creating a scientific poster in power point, entitled *biological, social, cultural and economic dimensions of tobacco smoking* and writing Introduction, Methodology, Results, Conclusions and Discussion. 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.

4. Creating an anti-smoking brochure entitled: *Dimensions of tobacco smoking, and suggestions for tackling the use of tobacco products.*

Students are provided with appropriate guidance in order to design a poster and health brochure as homework. 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 *Tobacco smoking, and suggestions for tackling the use of tobacco products* The five (5) lessons will be supervised by the teachers and developed by the students, with scheduled moments for checking the work development.
Visits to organizations interested in STEM and public health education could be organized. Additionally, a conference with STEM professionals could be organized. 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, scientists working on urban and environmental health, researchers of PAFSE consortium, etc.

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 concerning the results of a research question.
4. Design a questionnaire
5. Create a poster and present this in open schooling event.
6. Create a health brochure and distribute it in open schooling event.

Organization of the open schooling event:
2. Each project output (poster and health brochure) is presented by the students in a community setting.

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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. Additionally, 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 brochure 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.

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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. 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

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	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.
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.

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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 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.
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.

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	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.

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	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, 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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2.2. University of Ioannina (UOI) and Computer Technology Institute and Press “Diophantus” (CTI)[2]

AMENDMENTS[3]

Amendments of the revised version of the educational scenario entitled: *“The mathematical representation of an epidemic: the case of SIR (Susceptible, Infectious, or Recovered) modeling – High school (Senior high school) version”*

The pilot version of the scenario ‘The mathematical representation of an epidemic: the case of SIR (Susceptible, Infectious, or Recovered) modeling’ was modified in order to make two different versions of the scenarios: one for middle/junior high school grades (K7-9), and one for high/senior high school grades (K10-12). The modifications of the high school version are shown here.

Spelling and grammar errors were corrected. Scientific terms were replaced with more widely used terms (e.g., ‘didactic’ was replaced with ‘teaching’ in p. 4), in some cases.

Several activities were outlined with dotted frames to show that their enactment is optional.

Amendments of the revised version of the educational scenario entitled: *“The mathematical representation of an epidemic: the case of SIR (Susceptible, Infectious, or Recovered) modeling – Middle school (Junior high school) version”*

The pilot version of the scenario ‘The mathematical representation of an epidemic: the case of SIR (Susceptible, Infectious, or Recovered) modeling’ was modified in order to make two different versions of the scenarios: one for middle/junior high school grades (K7-9), and one for high/senior high school grades (K10-12). The modifications of the middle school version are shown here.

Spelling and grammar errors were corrected. Scientific terms were replaced with more widely used terms (e.g. ‘didactic’ was replaced with ‘teaching’ in p. 4), in some cases.

Several activities were outlined with dotted frames to show that their enactment is optional.

The activities were re-organized in order to decrease the duration of the scenario.

Amendments of the revised version of the educational scenario entitled: *“Social determinants of health during an epidemic/pandemic outbreak – High school (Senior high school) version”*

The pilot version of the scenario was modified in order to make two different versions of the scenarios: one for middle/junior high school grades (K7-9), and one for high/senior high school grades (K10-12). The modification of the high school version is shown here.

Spelling and grammar errors were corrected. Scientific terms where replaced in some cases with more widely used terms (e.g. ‘didactic’ was replaced with ‘teaching’ in p. 3).

Several activities were characterized as ‘optional’.

Several activities were outlined with dotted frames to show that their enactment is optional.

Amendments of the revised version of the educational scenario entitled: *“ Social determinants of health during an epidemic/pandemic outbreak – Middle school (Junior high school) version”*

The pilot version of the scenario was modified in order to make two different versions of the scenarios: one for middle/junior high school grades (K7-9), and one for high/senior high school grades (K10-12). The modification of the high school version is shown here.

Spelling and grammar errors were corrected. Scientific terms where replaced in some cases with more

[2] During the modification of the three of them, one more version came out. Thus, the three initial scenarios are now six. There are no changes for the scenario concerning students with intellectual disabilities.

[3] More specific references to the amendments are provided in the Annex.

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widely used terms (e.g. ‘didactic’ was replaced with ‘teaching’ in p. 3).
Several activities were characterized as ‘optional’.
Several activities were outlined with dotted frames to show that their enactment is optional.

Amendments of the revised version of the educational scenario entitled: *“Function of vaccines, vaccine hesitancy and misinformation – High school (Senior high school) version”*

The pilot version of the scenario ‘Function of vaccines, vaccine hesitancy and misinformation’ was modified in order to make two different versions of the scenarios: one for middle/junior high school grades (K7-9), and one for high/senior high school grades (K10-12). The modifications of the high school version are shown here.
Spelling and grammar errors were corrected. Scientific terms were replaced with more widely used terms (e.g. ‘didactic’ was replaced with ‘teaching’ in p. 4), in some cases.
Several activities were outlined with dotted frames to show that their enactment is optional.

Amendments of the revised version of the educational scenario entitled: *“Function of vaccines, vaccine hesitancy and misinformation – Middle school (Junior high school) version”*
The pilot version of the scenario ‘Function of vaccines, vaccine hesitancy and misinformation’ was modified in order to make two different versions of the scenarios: one for middle/junior high school grades (K7-9), and one for high/senior high school grades (K10-12). The modifications of the middle school version are shown here.
Spelling and grammar errors were corrected. Scientific terms were replaced with more widely used terms (e.g.,. ‘didactic’ was replaced with ‘teaching’ in p. 4), in some cases.
Several activities were outlined with dotted frames to show that their enactment is optional.
The duration of the scenario was downsized.

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2.2.1. The mathematical modeling of an epidemic and the importance of non-pharmaceutical interventions – High school

Main partner responsible
The Educational Approaches to Virtual Reality Lab (EARTH Lab), Department of Primary Education, 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.
Education on the enactment of non-pharmaceutical interventions and hygiene measures as a means of prevention of future epidemic outbreaks.
Understanding of the decisive importance personal behavior has for the public benefit during an epidemic.
Familiarization with cases of recent endemics, epidemic, and pandemics and, consequently, with the still constant problem of emerging and re-emerging infectious diseases.

Estimated duration & relevant subjects
14 teaching hours (extended version of the scenario) organized in continuous two-hour periods if possible.
10 teaching hours (short version of the scenario).
Designed for Biology, Science or Mathematics classes of high school (senior high school) grades (K10-12 grades). The scenario might also be applicable for Computer Science or Technology classes.
The Biology (or Science, or Mathematics, or Computer Science) teacher could cooperate with the English language teacher in order to combine Science Learning with English Language Instruction, according to

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the Content and Language integrated learning (CLIL). In this way both scientific literacy and English fluency are promoted. The learning sequence is appropriate for this method since all the DLOs and SERs are available in English.

Content
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 as scientific modelling – Convergence of sciences (natural sciences, medical sciences, mathematics, computer science) and technology towards handling complex problems.
Use and interpretation of mathematics (numerical data, indices, variables, graphs) in natural and health sciences (scientific and health numeracy).
Scientific work on authentic problems and data.
Authentic scientific data driven decision making.
Critical understanding and appraisal of medical 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.
Case fatality: Case fatality is the probability one has to die because of a disease in a given population, given that one has been infected by the disease (conditional probability). Supposing an epidemic has infected 50 people in a population of 1000 people, and 20 of them die. The case fatality rate is 20/50 = 40%. Case fatality depends on the pathogen attributes, the disease infectivity, the underlying health condition of the citizens, vaccination, and the healthcare system.
Communicable/infectious/contagious 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

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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 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, health condition of the susceptible person and vaccination.
Mortality: Mortality is the probability one has to die because of a disease in a given population. Supposing an epidemic has infected 50 people in a population of 1000 people, and 20 of them die. The mortality rate is 20/1000 = 2%. Mortality depends on the pathogen attributes, the disease infectivity, the underlying health condition of the citizens, vaccination, the healthcare system, and the frequency, or rareness, of the disease in the population.
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 number of the recovered. Some important conventions of the SIR model is that the population is usually considered to be stable, that all people have the same probabilities of infection and, sometimes, death, that the disease attributes (e.g. infectivity, disease duration, etc.) are considered the same for all the susceptible people of the population, and that recovered people cannot catch the disease again. The values of these three variables change over 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 health condition of the susceptible person, vaccination and external

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conditions (e.g. non pharmaceutical interventions such as medical masks and social distance).
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

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 organization, handling of variables, data driven conclusion making and communication about scientific topics. In structured inquiry students are given the research question to-be-answered, as well as detailed step-by-step guidance of the entire process of inquiry. In guided inquiry student are only given the research question to-be-answered and the decision-making processes about the research procedure are set up to them.
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.
Problem solving: The problem-based-learning approach includes students groups practicing higher thinking skills and making decisions in to analyze a given problem and propose solutions to it. At first, the problem settings are described to students along with the desirable aim, and some basic limitations. Each groups analyzes the problem and comes up with as more and as diverse solutions possible (creative thinking), and then evaluates these ideas (critical thinking) through group discussions, pros and cons comparisons, assessment according to criteria, pilot tests, tests, or other ways, and come down to a final proposed solution, as detailed as possible. After testing the proposed solution, or getting feedback on it, the group might have to repeat the steps of improve the solution.

Competences / Learning Goals

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Knowledge (Core Concepts)
a) Transdisciplinary concepts: Scientific modelling, graphs and mathematics in science, public health literacy.
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.

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.

Attitudes (Affective domain)
a) Attitudes and values: Acknowledgment of the fact that communicable diseases pose 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 organization 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.
Ease in making digital presentations.
Intermediate, or at least limited, fluency in English in case that DLOs and SERs other than the ones of the PAFSE repository are used.

School research project
Topics
How could an epidemic outbreak be represented in a quantitative way?
To what degree could a scientific model be efficient in representing precisely and confronting an epidemic?
How do characteristics of a communicable disease, citizen behaviour and social organization features influence the progress of an epidemic?

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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.
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 is 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

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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 methods

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 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

Inquiry-based-learning contextualization of the scenario's digital learning objects (structured inquiry,

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guided inquiry, case study, argumentation, problem solving)'.
Handling of the digital learning objects of the scenario.

Digital Learning Objects (DLOs)

DLOs created specifically for the needs of the PAFSE project

'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.

'Map and timeline of communicable diseases'
http://photodentro.pafse.eu/handle/8586/34
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.

'SIR model of an epidemic'
http://photodentro.pafse.eu/handle/8586/49
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.

'SIR model of an epidemic 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).

DLOs which have been taken from online resources

'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.

'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)

'Historical pandemics'
https://www.visualcapitalist.com/history-of-pandemics-deadliest/
Infographics depicting the harshness of certain historical pandemics. Constructed by Visual Capitalist.

'The SIR graph'

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https://cloud.anylogic.com/model/d465d1f5-f1fc-464f-857a-d5517edc2355?mode=SETTINGS
Dynamic visualization of an SIR graph.
'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.
'Spread of an airborne disease'
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.
'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.
'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.
'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.
'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.
'E-me platform H5P tools for the school project'
H5P tools of the e-me platform (https://e-me4all.eu/). By choosing 'e-me content' students can use the 'Course Presentation' tool to create an interactive and multimodal presentation, with texts, images, videos, short questions, etc, for the health promotion campaign.

Teaching -learning activities

Some educational activities have been framed in dotted frames, like the following one:

These activities could be seen as optional under conditions. Even though they are parts of the educational scenario, they are not inseparable ones, and they could be omitted if the teacher thinks so, mainly due to reasons relevant to restricted teaching time, limited student competences, or low student motives. This can be done according teacher's will and the omission of some framed activities does not affect the other ones, e. g. the framed activities of the 2nd, 5th, and 6th hours can be omitted, thus the framed activities of the 1st, 3rd, and 4th hours be carried hours properly. Some of the framed activities might be used as optional activities for more 'advances' student groups that end their task earlier than the rest, or as alternative, or optional homework for students interested.

1st teaching hour – Students' conceptions concerning non-pharmaceutical interventions and different transmission routes of diseases

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Learning objectives

Knowledge	Skills	Attitudes and Behaviours
Distinction between communicable and non-communicable diseases Naming disease transmission routes Naming non-pharmaceutical interventions applicable to each transmission route	Handling of digital simulations Data gathering Data-driven conclusion making	-

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. For example, 2-3 non-pharmaceutical interventions could be provided per student, maybe different for each student. There could be a numbered list with non-pharmaceutical interventions and each student could randomly be given 3 numbers.

The activity aims to the externalization of students' conceptions in terms with the function behind the non-pharmaceutical interventions (to what extent the biological or medical grounds behind these measures is known), the estimated efficacy of the interventions (research has shown that students do not consider such interventions efficient), and the estimated applicability of the interventions (students often do not consider them applicable). It must be made clear that it is not an evaluation test, nor are their answers be graded, and that they should sincerely express themselves.

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.

The teacher must make a free subscription to the Gizmos platform and issue class passwords for the students in order to use the simulation.

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., through air, respiratory droplets, water, animals, human contact, feces, insects, sexual intercourse, objects of shared use and body fluids). Then, each group is assigned to propose possible non-

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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).
During the group brainstorming, students are urged to find as many non-pharmaceutical interventions they can.

2nd teaching hour – The spread of recent epidemics and pandemics
Learning objectives

Knowledge	Skills	Attitudes and Behaviours
Distinction of endemics, epidemics, and pandemics Exemplification of recent epidemics and pandemics Explanation of the role of travelling in the spread of epidemics Explanation of how possible ways of the restriction of epidemics could work	Map reading Handling of digital simulations	Acknowledgement of the public health concern about communicable disease, even for Western countries Acknowledgement of the constant danger of disease (re)-emergence Appreciation of the importance of vaccination Awareness about geographical health disparities

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 medical 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.
The use of DLO I could be omitted in favor of time economy or simplicity, and the relevant tasks (e.g. finding diseases that affected students' country, distinction of endemics, epidemics, and pandemics) could be answered with DLO II.
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.
Measles, MERS, Zika disease and Avian Influenza might offer appropriate examples for this activity, without excluding other diseases, 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

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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.
COVID-19, and Swine Influenza might offer appropriate examples for this activity, without excluding other diseases, as well.
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. 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.
Measles, Rubella, HIV infections, and COVID-19 might offer appropriate examples for this activity, without excluding other diseases, as well.
The teacher could suggest students elaborate on certain diseases in the DLO II for each activity (e.g. COVID-19, Measles, MERS, etc.), that show characteristic examples of the phenomena examined. Then, students can navigate freely to find other examples in the same and in other diseases of the DLO.

3rd teaching hour – An introduction to SIR modelling
Learning objectives

Knowledge	Skills	Attitudes and Behaviours
Description of an epidemic with the SIR model. Explanation of the shape of the epidemic curve Explanation of the effect of transmissibility and infectivity of a disease on an epidemic outbreak Explanation of the effect of sociability during and epidemic outbreak Distinction between dependant and independent variables	Understanding SIR graphs Hypotheses testing via variable modifying Gathering and analysis of data Data-driven conclusion making to answer research questions Matching model elements to the real world Handling of digital simulations	-

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.
It is suggested to emphasize the differences between independent and dependant, and between qualitative and quantitative variables during all the inquiry activities (3rd to 8th hours), so that students are practiced in these distinctions.
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

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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.
Some SIR graphs for students' practice can be taken from the DLO III environment.
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' behaviors and the correspondent precautionary interventions depending on the transmission route.
The inquiry process with the DLO III is suggested to be as detailed as possible, because it is a relatively simple simulation. For instance, each inquiry procedure could include the statement of the research question, the characterization of the variables as dependant, independent, qualitative, and quantitative, the expression of the estimations for the results, the gathering of data, the extraction of conclusions, the explicit answer to the research question, and the matching to authentic life settings. Even if the points are poorly answered by some groups, the procedure is suggested to be followed –more or less- during all the inquiry activities during the following hours.

4th teaching hour – Using an SIR model to examine why it is important to 'flatten the curve'
Learning objectives

Knowledge	Skills	Attitudes and Behaviours
Argumentation for the need of keeping a low number of cases during an epidemic Evaluation of the severity of an epidemic	Understanding SIR graphs Discussion on scientific topics Handling of digital simulations	Appreciation of non-pharmaceutical interventions for the management of an epidemic Appreciation of non-pharmaceutical interventions for the promotion of Public Health

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.
Which consequence of an epidemic is the most important, depends on the disease and on the specific case examined. In general, it is the maximum number of infected cases, which needs to remain as low as possible, in order that the healthcare system is able to take care of the patients. Moreover the duration of the epidemic is expanded and it is more likely for more effective biomedical services (e.g. vaccines, medical treatments) to be developed against the disease.
Students, subsequently, modify the disease severity and healthcare system capacity and note down how

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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 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.
The activity above concerning a hypothetical infectious disease is an introductory activity for the following activities focusing on decision-making as part of the effective management of an epidemic. The activity could be omitted for now if necessary, because the learning objectives of the activity are served to a larger extent during the next activities with the aid of the next digital learning objects.

5th teaching hour – Using a more complex SIR model to study how decisive social distancing is during an epidemic

Learning objectives

Knowledge	Skills	Attitudes and Behaviours
Evaluation of the severity of an epidemic Evaluation of the effectiveness of non-pharmaceutical interventions Argumentation for the importance of social distancing Distinction of dependent and independent variables Distinction of quantitative and qualitative variables	Hypotheses testing via variable modifying Gathering and analysis of data Data-driven conclusion-making to answer research questions Match of model elements to the real world Discussion on scientific topics Handling of digital simulations	Appreciation of the importance of non-pharmaceutical interventions Social distancing during and epidemic Adoption of experimentation as a way of studying the natural world Respect of research ethics (e.g. sincere description of research actions and results)

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.
A short guide with the initial values for the simulation parameters to-be-used should be given to students for the initiation of the inquiry activity, since some parameters values differ from the default ones (e.g. asymptomatic rate).
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

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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. They note down how much the social distancing value should be, in order to be a tolerable situation in terms of Public Health.
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.
The rule of triple repetition of each test is not necessary to be followed at the last activity, in favor of saving time. If the teacher considers the rule as quite time consuming, it can be fully omitted after the two first time of application by each student group.

6th teaching hour – Using an SIR model to examine how quarantining, central locations and interconnected communities affect the progress of an epidemic

Learning objectives

Knowledge	Skills	Attitudes and Behaviours
Evaluation of the severity of an epidemic Evaluation of the effectiveness of non-pharmaceutical interventions Argumentation for quarantining Argumentation for the avoidance of traveling Distinction of independent and dependent variables Distinction of qualitative and quantitative variables	Design of research approaches to answer to research questions Hypotheses testing via parameter modifying Data gathering and analysis Data driven conclusion making to answer research questions Match of model elements to the real world Discussion on scientific topics Critical thinking and decision-making Handling of digital simulations	Appreciation of non-pharmaceutical interventions for the management of an epidemic Enforcement of quarantine Avoidance of traveling during epidemics Adoption of experimentation as a way of studying the natural world Respect of research ethics (e.g. sincere description of research actions and results)

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,

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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 class.

During this hour students have to work much more independently, receive much less guidance, and make several decisions on their own in order to study the three research questions. This study is expected to need more time to be carried out for the majority of student groups. The aim is not to follow certain predetermined research steps, like in the previous hours, but to practice some basic skills of methodology, and research design to study research questions. This is a quite demanding activity for the majority of student groups of this age, and the groups are expected to proceed the assigned inquires with different paces. It is suggested to have each group proceed independently and complete the activities they catch up with. The deeper aim of the procedure if to have each group completed, or nearly completed, at least one research question, given the necessary assistance (scaffolding), feedback, or guidance questions by the teacher.

7th teaching hour – Using an SIR model to examine parameters affecting the spread of an airborne epidemic

Learning objectives

Knowledge	Skills	Attitudes and Behaviours
Evaluation of the severity of an epidemic Evaluation of the effectiveness of non-pharmaceutical interventions Description of the transmission mechanism of an airborne disease Argumentation for the use of medical masks Distinction of independent and dependent variables Distinction of qualitative and	Design of research approaches to answer to research questions Hypotheses testing via parameter modifying Data gathering and analysis Data driven conclusion making to answer research questions Match of model elements to the real world Discussion on scientific topics Critical thinking and decision-making Handling of digital simulations	Appreciation of non-pharmaceutical interventions for the management of an epidemic Enforcement of non-pharmaceutical interventions during an epidemic Use of medical masks Adoption of experimentation as a way of studying the natural world Respect of research ethics (e.g. sincere description of research

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quantitative variables		actions and results)

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).
The exploration of the virtual environment of the simulation could be done through direct instruction with the aid of a projector machine.
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 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. SERs IV and V could be projected with a projector machine and the reason of the high effectiveness of the use of medical masks could be explained in the grounds of these SERs. Students are expected reach themselves to this conclusion.
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.
The comparisons do not have to be as detailed as the previous ones.
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.
The activity, which is a series of numerous alternative options for activities, is might be optional and aiming only to 'advanced' groups, that have completed the previously assigned tasks earlier than the other student groups.

<u>8th teaching hour – Using an SIR model to take policy decisions for a hypothetical epidemic</u>
Learning objectives

Knowledge	Skills	Attitudes and Behaviours
Evaluation of the severity of an epidemic Evaluation of the policy measures concerning the management of an epidemic	Design of research approaches to answer to research questions Data driven conclusion making to answer research questions Match of model elements to the	Appreciation of the difficulty of taking policy decisions Appreciation of the role of models in science Acknowledgement of the

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Comparison of scientific models representing the same natural phenomenon Explanation of the effectiveness of scientific models	real world Discussion on scientific topics Critical thinking and decision-making Problem solving in authentic settings	existence of alternative research approaches in science Acknowledgement of the element of intrinsic uncertainty in science

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.

The activity, which comprises of a series of numerous alternative options for activities, is might be optional and aiming only to 'advanced' groups, that have completed the previously assigned tasks earlier than the other student groups. It would be desirable each group to have completed at least one inquiry independently, and most groups to have completed at least two.

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.

The discussion might focus on 2-4 indicative questions, on which most student groups answered.

Next, each group is assigned with 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.

The activity is optional and it is an introduction to the research project, in fact. It could be omitted, at the moment, since it is done to a greater extent in the following activities. The time could be afforded for the more detailed study of the student inquiries and their different methodologies and approaches.

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 and commented in a final conceptualization of the nature, the function and the usefulness of a scientific model.

The comparison of the three SIR models with one another, and with the real world are quite important for the distinction between the concepts of models and the real natural phenomena in the students' conceptualizations.

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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)

Learning objectives

Knowledge	Skills	Attitudes and Behaviours
Exemplification of policy measures for the management of an epidemic Explanation of the function of policy measures for the management of an epidemic Evaluation of the effectiveness of policy measures for the management of an epidemic	Hypotheses testing by using models Match of model elements to the real world Critical thinking, argumentation and decision-making Reflection on decision-making Communication and collaboration Discussion on scientific topics	Acknowledgment of the complex nature of taking policy decisions Acknowledgement of the complex nature of a real society

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, which is a problem-based-learning activity. 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. Hints, feedback, or guiding questions should be provided to students when they feel blocked or run out of ideas, specifically adapted to each student group.

10th teaching hour - Examining how close SIR models are to real epidemic cases (School project)

Learning objectives

Knowledge	Skills	Attitudes and Behaviours
Explanation of the differences of scientific models from the real world	Navigation in databases Match of model elements to the real world	Adoption of experimentation as a way of studying hypotheses Respect of scientific ethics (e.g.

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	Design of research approaches Data-driven conclusion-making Critical thinking and decision-making Communication and cooperation Discussion on scientific topics	sincere description of research actions and results)

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, which is a guided inquiry activity. It is concerned with 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 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.

The second part of the research project, which is the precision test of the SIR models in comparison with the authentic epidemic data, is clearly of greater difficulty. If the teacher considers it would be more appropriate, they could offer the student groups the choice to work alternatively on the first or the second project parts, according to their personal preferences. This means a reorganization of the project activities and time management.

11th teaching hour – Drawing conclusions based on students' work (School project)

Learning objectives

Knowledge	Skills	Attitudes and Behaviours
Explanation of the differences of scientific models from the real world	Navigation in databases Match of model elements to the real world Design of research approaches Data-driven conclusion-making Critical thinking and decision-making Communication and cooperation Discussion on scientific topics	Adoption of experimentation as a way of studying hypotheses Respect of scientific ethics (e.g. sincere description of research actions and results)

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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 activity is suggested providing that the school class climate among student is suitable for the proper cooperation and mutual help among students about the lesson.
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)
Learning objectives

Knowledge	Skills	Attitudes and Behaviours
Explanation of way that non-pharmaceutical interventions work Argumentation for the implementation of non-pharmaceutical interventions	Critical thinking and argumentation Communication and cooperation Discussion on scientific topics Presentation of scientific issues to the general public	Implementation of non-pharmaceutical interventions

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 (SER IX), 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)
Learning objectives

Knowledge	Skills	Attitudes and Behaviours
-	Provision of feedback and active listening Communication and	Development of positive attitude towards feedback

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	presentation skills Reflection on the learning procedure	

Teaching phase according to the inquiry & project based instructional model: Project presentation – Final assessment – Self-reflective phase
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.

Short version of the scenario (10 teaching hours)
The initial (expanded) version of the educational scenario lasts for 14 teaching hours. Difficulties that may arise due to its long duration (e.g. alignment with the Curriculum, availability of rooms, or resources). For that reason a shorter version of the scenario of 10 teaching hours is provided, which can be opted for if the teacher thinks so. The suggested modifications to the structure of the scenario are the following ones:

Expanded version of the scenario (14 hours)	**Short version of the scenario (10 hours)**	**Modifications**
1st-2nd hours	1st-2nd hours	Remaining the same.
3rd-4th hours	3rd hour (fusion)	Some activities from the initial two-hour session are chosen and carried out. The chosen activities are the familiarization with the SIR graph, a consise study of transmissibility (not infectiousness) and sociability, and the importance of healthcare system capacity. The aims of the other activities can be covered by the rest of the scenario.
5th-8th hours	4th-7th hours	Remaining the same.
9th-12th hours	8th-9th hours (reorganization)	Each student group is responsible only for one task (management plan of an epidemic, study of the model precision, or the development of informative presentation), which groups have chosen on their owned, or assigned by the teacher according to their judgment, Two hours considered sufficient time for the necessary activities and the development of the

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		final deliverable for each group, since every group is responsible only for one task, now. The minimum number of presentation slides for the task of the informative campaign might be increased in order to fit the two-hour session, according to the teacher's judgment.
13th-14th hours	10th hour (fusion)	The project presentations are fused into a single teaching hour, because of the decrease of deliverables per group of students. The presentation time for each group is also modified. The final feedback about the lesson is done anonymously and in written, to save time.

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:

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.

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.

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.

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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.
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.
Academics or university professors with relevant expertise.
Members of the PAFSE consortium with relevant expertise.
II. Educational visits
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:
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.
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).
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.
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 Behaviors

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

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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
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

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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 eaths 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

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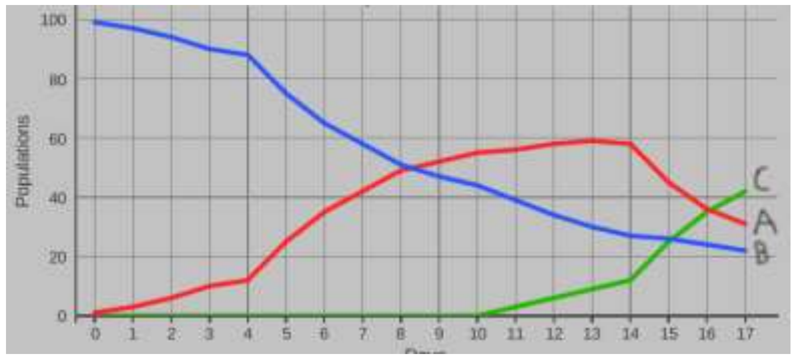
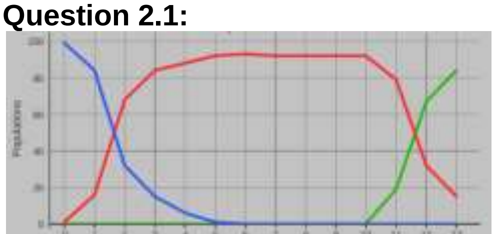
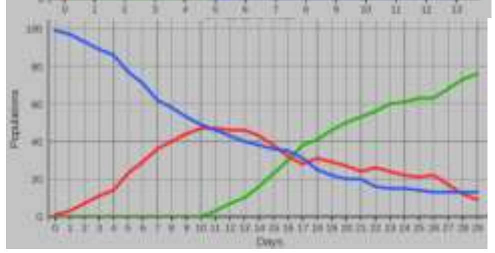
	C) does not influence the efforts of the restriction of the disease
7. Recognises the nature of a scientific model	**Question 7.1:** A scientific model is … A) a selective representation of a natural phenomenon which can contribute to original scientific research B) a selective representation of a natural phenomenon having solely educational value C) a close replication of a natural phenomenon which might have scientific ore educational value
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 …

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	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
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

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	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
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
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.

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	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
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

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	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
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

2.2.2. The mathematical modeling of an epidemic and the importance of non-pharmaceutical interventions – Middle school

Main partner responsible
The Educational Approaches to Virtual Reality Lab (EARTH Lab), Department of Primary Education, 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

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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 school project with three options. The first option 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 option 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 option is the development 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.
Education on the enactment of non-pharmaceutical interventions and hygiene measures as a means of prevention of future epidemic outbreaks.
Understanding of the decisive importance personal behavior has for the public benefit during an epidemic.
Familiarization with cases of recent endemics, epidemic, and pandemics and, consequently, with the still constant problem of emerging and re-emerging infectious diseases.

Estimated duration & relevant subjects

12 teaching hours (extended version of the scenario) organized in continuous two-hour periods if possible.
6 teaching hours (short version of the scenario).
Designed for Biology, Science or Mathematics classes of middle school (junior high school) grades (K7-9 grades). The scenario might also be applicable for Computer Science or Technology classes.
The Biology (or Science, or Mathematics, or Computer Science) teacher could cooperate with the English language teacher in order to combine Science Learning with English Language Instruction, according to the Content and Language integrated learning (CLIL). In this way both scientific literacy and English fluency are promoted. The learning sequence is appropriate for this method since all the DLOs and SERs are available in English.

Content

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 as scientific modelling – Convergence of sciences (natural sciences, medical sciences, mathematics, computer science) and technology towards handling complex problems.
Use and interpretation of mathematics (numerical data, indices, variables, graphs) in natural and health

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sciences (scientific and health numeracy).
Scientific work on authentic problems and data.
Authentic scientific data driven decision making.
Critical understanding and appraisal of medical 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.
Case fatality: Case fatality is the probability one has to die because of a disease in a given population, given that one has been infected by the disease (conditional probability). Supposing an epidemic has infected 50 people in a population of 1000 people, and 20 of them die. The case fatality rate is 20/50 = 40%. Case fatality depends on the pathogen attributes, the disease infectivity, the underlying health condition of the citizens, vaccination, and the healthcare system.
Communicable/infectious/contagious 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 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, health condition of the susceptible person and vaccination.
Mortality: Mortality is the probability one has to die because of a disease in a given population. Supposing an epidemic has infected 50 people in a population of 1000 people, and 20 of them die. The mortality rate

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is 20/1000 = 2%. Mortality depends on the pathogen attributes, the disease infectivity, the underlying health condition of the citizens, vaccination, the healthcare system, and the frequency, or rareness, of the disease in the population.
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 number of the recovered. Some important conventions of the SIR model is that the population is usually considered to be stable, that all people have the same probabilities of infection and, sometimes, death, that the disease attributes (e.g. infectivity, disease duration, etc.) are considered the same for all the susceptible people of the population, and that recovered people cannot catch the disease again. The values of these three variables change over 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 health condition of the susceptible person, vaccination and external conditions (e.g. non pharmaceutical interventions such as medical masks and social distance).
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

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

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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 organization, handling of variables, data driven conclusion making and communication about scientific topics. In structured inquiry students are given the research question to-be-answered, as well as detailed step-by-step guidance of the entire process of inquiry. In guided inquiry student are only given the research question to-be-answered and the decision-making processes about the research procedure are set up to them.
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.
Problem solving: The problem-based-learning approach includes students groups practicing higher thinking skills and making decisions in to analyze a given problem and propose solutions to it. At first, the problem settings are described to students along with the desirable aim, and some basic limitations. Each groups analyzes the problem and comes up with as more and as diverse solutions possible (creative thinking), and then evaluates these ideas (critical thinking) through group discussions, pros and cons comparisons, assessment according to criteria, pilot tests, tests, or other ways, and come down to a final proposed solution, as detailed as possible. After testing the proposed solution, or getting feedback on it, the group might have to repeat the steps of improve the solution.

<u>Competences / Learning Goals</u>
Knowledge (Core Concepts)
a) Transdisciplinary concepts: Scientific modelling, graphs and mathematics in science, public health literacy.
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.

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

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mathematics in scientific contexts, handling of educational simulations.

Attitudes (Affective domain)
a) Attitudes and values: Acknowledgment of the fact that communicable diseases pose 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 organization 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.
Ease in making digital presentations.
Intermediate, or at least limited, fluency in English in case that DLOs and SERs other than the ones of the PAFSE repository are used.

School research project
Topics
How could an epidemic outbreak be represented in a quantitative way?
To what degree could a scientific model be efficient in representing precisely and confronting an epidemic?
How do characteristics of a communicable disease, citizen behaviour and social organization features influence the progress of an epidemic?
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 is 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 methods
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 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-

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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
Inquiry-based-learning contextualization of the scenario's digital learning objects (structured inquiry, guided inquiry, case study, argumentation, problem solving)'.
Handling of the digital learning objects of the scenario.

Digital Learning Objects (DLOs)

DLOs created specifically for the needs of the PAFSE project
'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.
'Map and timeline of communicable diseases'
http://photodentro.pafse.eu/handle/8586/34
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.

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'SIR model of an epidemic'
http://photodentro.pafse.eu/handle/8586/49
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.
'SIR model of an epidemic 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).

DLOs which have been taken from online resources
'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)
'Historical pandemics'
https://www.visualcapitalist.com/history-of-pandemics-deadliest/
Infographics depicting the harshness of certain historical pandemics. Constructed by Visual Capitalist.
'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.
'Spread of an airborne disease'
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.
'Face masks against the spread of airborne diseases'
https://www.youtube.com/watch?v=xEp-SdgI9AU
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.
'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.
'E-me platform H5P tools for the school project'
H5P tools of the e-me platform (https://e-me4all.eu/). By choosing 'e-me content' students can use the 'Course Presentation' tool to create an interactive and multimodal presentation, with texts, images, videos, short questions, etc, for the health promotion campaign.

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Teaching -learning activities

Some educational activities have been framed in dotted frames, like the following one:

These activities could be seen as optional under conditions. Even though they are parts of the educational scenario, they are not inseparable ones, and they could be omitted if the teacher thinks so, mainly due to reasons relevant to restricted teaching time, limited student competences, or low student motives. This can be done according teacher's will and the omission of some framed activities does not affect the other ones, e. g. the framed activities of the 2nd, 5th, and 6th hours can be omitted, thus the framed activities of the 1st, 3rd, and 4th hours be carried hours properly. Some of the framed activities might be used as optional activities for more 'advances' student groups that end their task earlier than the rest, or as alternative, or optional homework for students interested.

1st teaching hour – Students' conceptions concerning non-pharmaceutical interventions and different transmission routes of diseases

Learning objectives

Knowledge	Skills	Attitudes and Behaviours
Distinction between communicable and non-communicable diseases Naming disease transmission routes Naming non-pharmaceutical interventions applicable to each transmission route	Handling of digital simulations Data gathering Data-driven conclusion making	-

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 emphasized 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. For example, 2-3 non-pharmaceutical interventions could be provided per student, maybe different for each student. There could be a numbered list with non-pharmaceutical interventions and each student could randomly be given 3 numbers.

The activity aims to the externalization of students' conceptions in terms with the function behind the non-pharmaceutical interventions (to what extent the biological or medical grounds behind these measures is known), the estimated efficacy of the interventions (research has shown that students do not consider such interventions efficient), and the estimated applicability of the interventions (students often do not consider them applicable). It must be made clear that it is not an evaluation test, nor are their answers be graded, and that they should sincerely express themselves.

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Afterwards, the entire class participates in a brainstorming process mentioning different disease transmission routes. The teacher adds routes that have not been expressed (e.g., through air, respiratory droplets, water, animals, human contact, feces, insects, sexual intercourse, objects of shared use and 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).
During the group brainstorming, students are urged to find as many non-pharmaceutical interventions they can.

2nd teaching hour – The spread of recent epidemics and pandemics
Learning objectives

Knowledge	Skills	Attitudes and Behaviours
Distinction of endemics, epidemics, and pandemics Exemplification of recent epidemics and pandemics Explanation of the role of travelling in the spread of epidemics Explanation of how possible ways of the restriction of epidemics could work	Map reading Handling of digital simulations	Acknowledgement of the public health concern about communicable disease, even for Western countries Acknowledgement of the constant danger of disease (re)-emergence Appreciation of the importance of vaccination Awareness about geographical health disparities

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 medical 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.
The use of DLO I could be omitted in favor of time economy or simplicity, and the relevant tasks (e.g. finding diseases that affected students’ country, distinction of endemics, epidemics, and pandemics) could be answered with DLO II.
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.
Measles, MERS, Zika disease and Avian Influenza might offer appropriate examples for this activity, without excluding other diseases, as well.

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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.
COVID-19, and Swine Influenza might offer appropriate examples for this activity, without excluding other diseases, as well.
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. 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.
Measles, Rubella, HIV infections, and COVID-19 might offer appropriate examples for this activity, without excluding other diseases, as well.
The teacher could suggest students elaborate on certain diseases in the DLO II for each activity (e.g. COVID-19, Measles, MERS, etc.), that show characteristic examples of the phenomena examined. Then, students can navigate freely to find other examples in the same and in other diseases of the DLO.

3rd teaching hour – An introduction to SIR modelling
Learning objectives

Knowledge	**Skills**	**Attitudes and Behaviours**
Description of an epidemic with the SIR model. Explanation of the shape of the epidemic curve Explanation of the effect of transmissibility and infectivity of a disease on an epidemic outbreak Explanation of the effect of sociability during and epidemic outbreak Distinction between dependant and independent variables	Understanding SIR graphs Hypotheses testing via variable modifying Gathering and analysis of data Data-driven conclusion making to answer research questions Matching model elements to the real world Handling of digital simulations	-

Teaching phase according to the inquiry & project based instructional model: Main inquiry
For the following teaching hours (3rd to 6th) 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. After the first two teaching hours they change the SIR simulation they work on, moving from a simpler to the more complex and realistic ones. The SIR models they use are DLOs III, V 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.
It is suggested to emphasize the differences between independent and dependant, and between qualitative

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and quantitative variables during all the inquiry activities (3rd to 6th hours), so that students are practiced in these distinctions.
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 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. The shape and the meaning of the SIR graphs should be taught explicitly with numerous examples and case studies. Different SIR graphs and epidemic curves and be compared and contrasted to one another. The video SER II could be shown in order to match the real progress of an epidemic outbreak to the shape of the SIR graph in real time.
Some SIR graphs for students' practice can be taken from the DLO III environment.
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.
The inquiry process with the DLO III is suggested to be as detailed as possible, because it is a relatively simple simulation. For instance, each inquiry procedure could include the statement of the research question, the characterization of the variables as dependant, independent, qualitative, and quantitative, the expression of the estimations for the results, the gathering of data, the extraction of conclusions, the explicit answer to the research question, and the matching to authentic life settings. Even if the points are poorly answered by some groups, the procedure is suggested to be followed –more or less- during all the inquiry activities during the following hours.

4th teaching hour – Using an SIR model to examine why it is important to 'flatten the curve'
Learning objectives

Knowledge	Skills	Attitudes and Behaviours
Argumentation for the need of keeping a low number of cases during an epidemic Evaluation of the severity of an epidemic	Understanding SIR graphs Discussion on scientific topics Handling of digital simulations	Appreciation of non-pharmaceutical interventions for the management of an epidemic Appreciation of non-pharmaceutical interventions for the promotion of Public Health

Teaching phase according to the inquiry & project based instructional model: Main inquiry
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' behaviors and the correspondent precautionary interventions depending on the transmission route.
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

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would be.
Which consequence of an epidemic is the most important, depends on the disease and on the specific case examined. In general, it is the maximum number of infected cases, which needs to remain as low as possible, in order that the healthcare system is able to take care of the patients. Moreover the duration of the epidemic is expanded and it is more likely for more effective biomedical services (e.g. vaccines, medical treatments) to be developed against the disease.
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 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.
The activity above concerning a hypothetical infectious disease is an introductory activity for the following activities focusing on decision-making as part of the effective management of an epidemic. The activity could be omitted for now if necessary, because the learning objectives of the activity are served to a larger extent during the next activities with the aid of the next digital learning objects.

5th teaching hour – Using a more complex SIR model to study how decisive non-pharmaceutical interventions are during an epidemic

Learning objectives

Knowledge	Skills	Attitudes and Behaviours
Evaluation of the severity of an epidemic Argumentation for the importance of social distancing, quarantining and avoidance of travelling Distinction of dependent and independent variables Distinction of quantitative and qualitative variables	Hypotheses testing via variable modifying Gathering and analysis of data Data-driven conclusion-making to answer research questions Match of model elements to the real world Discussion on scientific topics Handling of digital simulations	Appreciation of the importance of non-pharmaceutical interventions Social distancing, quarantining, and avoidance of travelling during an epidemic Adoption of experimentation as a way of studying the natural world Respect of research ethics (e.g. sincere description of research actions and results)

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 V) students continue the inquiry process for this teaching hour, by applying and expanding their attained knowledge and skills. DLO V 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.
A short guide with the initial values for the simulation parameters to-be-used should be given to students for the initiation of the inquiry activity, since some parameters values differ from the default ones (e.g.

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asymptomatic rate). Moreover, it would be useful to have the simulation centrally shown with a projector machine, so as to guide students step-by-step in order to scaffold students with the inquiry process. It would be useful because the simulation is complex, includes several variables and the simulation is in English.

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) and note down the variables of epidemic duration, cumulative infected percentage and maximum infected percentage.

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. Half of the groups are assigned to study a disease of low infectivity (low infectious radius) and the other half of the groups study a disease of high infectious disease (high infectious radius). They organize the collected data in tables and contrast them with the reference values and with a hypothetical limit of healthcare system capacity. They note down how much the social distancing value should be, in order to be a tolerable situation in terms of Public Health.

Afterwards, the teacher organizes the indicative results of the four cases (low infectivity/no measures, low infectivity/social distancing, high infectivity/no measures, high infectivity/social distancing). The cases are compares in pairs, and conclusions are drawn on the effect of infectivity on the degree of precautionary interventions needed to be taken and students discuss what ‘social distancing’ means in real life conditions.

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.

The teacher shows what happens if the modes ‘Quarantine’, ‘Central location’, and ‘Communities’ are chosen with the aid of a projector machine. Students make short assumptions what would happen in each case and, then, they see if they were right or wrong. They discuss why this result happens in each case, and what it could mean in authentic life settings.

A short, yet more extensive study, study on one of the three last options might be assigned in groups as homework. They should explain how the selected condition affects the epidemic and why. Moreover they could match the selected cases in real life settings, e.g., what central locations are, how quarantine could be achieved, and how could travelling be restricted.

6th teaching hour – Using an SIR model to examine parameters affecting the spread of an airborne epidemic

Learning objectives

Knowledge	Skills	Attitudes and Behaviours
Evaluation of the severity of an epidemic Evaluation of the effectiveness of non-pharmaceutical interventions Description of the transmission mechanism of an airborne disease Argumentation for the use of	Hypotheses testing via parameter modifying Data gathering and analysis Data driven conclusion making to answer research questions Match of model elements to the real world Discussion on scientific topics Handling of digital simulations	Appreciation of non-pharmaceutical interventions for the administration of an epidemic Enforcement of non-pharmaceutical interventions during an epidemic Use of medical masks Adoption of experimentation as

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medical masks		a way of studying the natural world Respect of research ethics (e.g. sincere description of research actions and results)

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' behavior 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).
The exploration of the virtual environment of the simulation could be done through direct instruction with the aid of a projector machine.
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 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 III could be utilized. SER III 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 IV could be shown, which reveals how a mask can disrupt the flow of exhalation and respiratory droplets, with the aid of an infrared camera. SERs III and IV could be projected with a projector machine and the reason of the high effectiveness of the use of medical masks could be explained in the grounds of these SERs. Students are expected reach themselves to this conclusion.
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.
The comparisons do not have to be as detailed as the previous ones.
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, 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.
The activity, which is a series of numerous alternative options for activities, is might be optional and aiming only to 'advanced' groups, that have completed the previously assigned tasks earlier than the other student groups.

7th teaching hour – Using an SIR model to take policy decisions for a hypothetical epidemic
Learning objectives

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Knowledge	Skills	Attitudes and Behaviours
Evaluation of the severity of an epidemic Evaluation of the policy measures concerning the management of an epidemic Comparison of scientific models representing the same natural phenomenon	Match of model elements to the real world Discussion on scientific topics Critical thinking and decision-making Problem solving in authentic settings	Appreciation of the difficulty of taking policy decisions Appreciation of the role of models in science Acknowledgement of the element of intrinsic uncertainty in science

Teaching phase according to the inquiry & project based instructional model: Application of new knowledge and skills through inquiry

Students discuss in class about the inquiries they have made. The teacher chooses certain research questions, namely two or three. 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. Moreover, they are urged to come up with different alternative research designs than the ones been done. The methodological options, the results and the interpretations of each group are discussed. Differences among student 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 with 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.

The activity is optional and it is an introduction to the research project, in fact. It could be omitted, at the moment, since it is done to a greater extent in the following activities. The time could be afforded for the more detailed study of the student inquiries and their different methodologies and approaches.

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 to be made. Students express themselves whether the integral uncertainty of a model cancels its predictive or even its scientific value.

The comparison of the three SIR models with one another, and with the real world are quite important for the distinction between the concepts of models and the real natural phenomena in the students' conceptualizations.

8th – 9th teaching hours - Using SIR models for policy making, model precision checking and informing the public (School project)

Learning objectives (depending on the school project selected)

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Knowledge	Skills	Attitudes and Behaviours
Explanation of the function of policy measures for the administration of an epidemic Evaluation of the effectiveness of policy measures for the administration of an epidemic Explanation of the differences of scientific models from the real world Explanation of way that non-pharmaceutical interventions work Argumentation for the implementation of non-pharmaceutical interventions	Hypotheses testing by using models Match of model elements to the real world Critical thinking, argumentation and decision-making Communication and collaboration Critical thinking, decision-making and problem solving Discussion on scientific topics Presentation skills for the general public	Acknowledgment of the complex nature of taking policy decisions Acknowledgement of the complex nature of a real society Adoption of experimentation as a way of studying hypotheses Respect of scientific ethics (e.g. sincere description of research actions and results) Enforcement of non-pharmaceutical interventions

Teaching phase according to the inquiry & project based instructional model: Project initiation – project development

In order to make links 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.

Students form four- or five-member groups in order to take upon their project task. They have the chance to select among three different project options that have different topics, include quite different tasks and demand different skills.

The first project option is a problem-based-learning activity. Each group gets a card with the biological and epidemiological features of the recent COVID-19 pandemic for a cert ainarea in a certain period of time. Students enter the relevant data into one or more of ~~the~~ three SIR simulations they have used (DLOs III, IV, V) in a 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 as functional and viable as possible, 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 if possible. 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. Hints, feedback, or guiding questions should be provided to students when they feel blocked or run out of ideas, specifically adapted to each student group. Students can, also, navigate in the database SER V, where they can find ideas about 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. Finally students 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

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measures, and mainly to the rationale behind each choice. A detailed worksheet in order to scaffold students that choose this project is necessary, in order to write a final report.
The second project option is a guided inquiry activity. It is considered of higher difficulty than the other options, and it might be more appropriate for students with strong interests and tendencies in Mathematics and Science. It is concerned with the test of the compatibility of one of the three SIR models studied (DLOs III, IV and V) 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 SER V. The only necessary requirement is the chosen period to be 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 V. 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 the authentic data as shown in the databases SERs V. The interpretation of the differences by each group is of high importance for this activity. A detailed worksheet in order to scaffold students that choose this project are necessary, in order to carry out the research, draw conclusion, and write a final report. 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.
The second part of the research project, which is the precision test of the SIR models in comparison with the authentic epidemic data, is clearly of greater difficulty it might be more appropriate for students with strong interests and tendencies in Mathematics and Science. The database SER V is available in English and Greek.
The third project option is a science communication one, and it is more appropriate for students having less ease in Science and Mathematics. It does not focus on inquiry and experimentation skills. It focuses on general conceptual understanding and communication skills, instead. 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 six actions ~~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). They must use resources (e.g. screenshots from the SIR simulations, or videos) to explain how each intervention work, why is important, and in what cases they can be used. Each group is tasked to make a short digital presentation with ten ~~four~~ slides (SER ~~IX~~ VI), one for each intervention, by using the appropriate software. Students can, also, include information about recent epidemics, endemics and pandemics, as well as information and resources found on the Internet. 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.
During the 9th teaching hour student groups having selected the same project options briefly discuss the progress of their projects. In that way they are expected to exchange ideas concerning the choices they made, complementary options and methodologies, ideas have not thought of, difficulties they found
The activity is suggested providing that the school class climate among student is suitable for the proper cooperation and mutual aid among students about the lesson.
The final project outcome of the first option is an administration report or diagram. The final project outcome of the second option is a scientific report. The final project outcome is a digital presentation. The teacher has to constantly monitor students' progress and support them by helping them to come over the difficulties, asking them guiding questions, suggesting ways for improvement, and highlighting cases that

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students had not thought of.

11th-12th teaching hour – Presentation of the project outcomes (School project)

Learning objectives

Knowledge	Skills	Attitudes and Behaviours
-	Provision of feedback and active listening Communication and presentation skills Reflection on the learning procedure	Development of positive attitude towards feedback

Teaching phase according to the inquiry & project based instructional model: Project presentation – Final assessment – Self-reflective phase

Each group has completed one of 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 project options. 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.

Short version of the scenario (6 teaching hours)

The initial (expanded) version of the educational scenario lasts for 12 teaching hours. Difficulties that may arise due to its long duration (e.g., alignment with the Curriculum, availability of rooms, or resources). For that reason a shorter version of the scenario of 6 teaching hours is provided, which can be opted for if the teacher thinks so. The suggested modifications to the structure of the scenario are the following ones:

Expanded version of the scenario (12 hours)	Short version of the scenario (10 hours)	Modifications
1st-2nd hours	1st hour (fusion)	Some activities from the initial two-hour session are chosen and carried out. The chosen activities are the group brainstorming on transmission routs, and the use of DLO II (not DLO I) to on the distinction of epidemics, endemics, pandemics, the rise and spread of epidemics, and the decrease of epidemics.
3rd-4th hours	2nd hour (fusion)	Some activities from the initial two-hour session are

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		chosen and carried out. The chosen activities are the familiarization with the SIR graph, a concise study of transmissibility (not infectiousness) and sociability, and the importance of healthcare system capacity. The aims of the other activities can be covered by the rest of the scenario.
5th hour	(omitted)	The activity is omitted since the concept of SIR is already covered, and the English language and big number of variables might confuse some students.
6th-7th hour	3rd hour (fusion)	Some activities from the initial two-hour session are chosen and carried out. The chosen activities are the familiarization with the new environment, the test and explanation of the effectiveness of mask using, and a short problem solving on the administration of a disease.
8th-10th hours	8th-9th hours (fusion)	The demands of the project are decreased. Only the first and the third project options are given, since the second action needs more time. The activity of ideas exchanges is done only in a form of a short classroom discussion. The administration plan (outcome of the first option) is less detailed, and the informative presentation (outcome of the third option) is decreased in topics and slides.
11th-12th hours	6th hour (fusion)	The project presentations are fused into a single teaching hour. The presentation time for each group is also modified. The final feedback about the lesson is done anonymously and in written, to save time.

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.

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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 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:
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.
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.
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.
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.
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.
Academics or university professors with relevant expertise.
Members of the PAFSE consortium with relevant expertise.
II. Educational visits
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:
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.
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).
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.
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 Behaviors

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

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	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
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

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	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
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
Skills	

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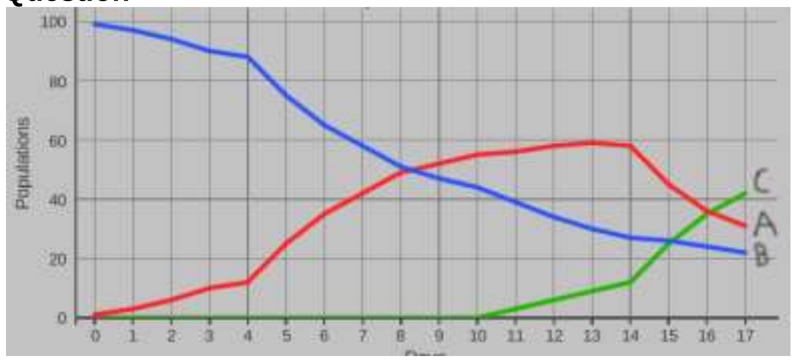
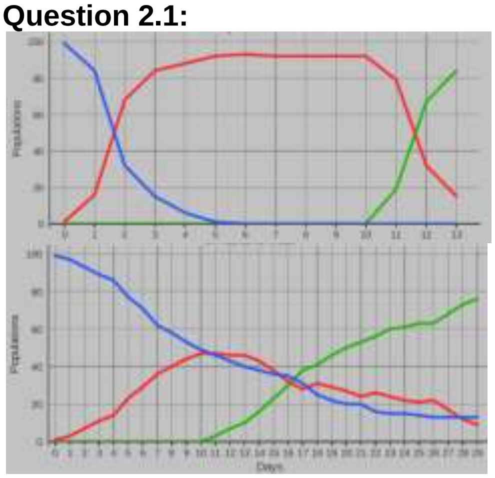
1. Interprets graphic and numerical SIR data	**Question 1.1:**  The graph shows the evolution of an epidemic. The letters A and B stand for … A) the numbers of infectious and susceptible people respectively B) the numbers of susceptible and recovered people respectively C) the numbers of infectious and 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.

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	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
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
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

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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
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

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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
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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2.2.3. Social determinants of health during an epidemic/pandemic outbreak – High School

Main partner responsible
The Educational Approaches to Virtual Reality Laboratory (EARTH Lab), Department of Primary Education, 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 and health disparities pose a serious issue in public health promotion. Students have to be aware of this problem in order to evolve to active citizens.
The notion of health is contextualized in authentic societal settings (health policies), and an authentic way of health-related decision-making, including emotional, social, economic, and ethical factors.
The inclusion of social determinants of health in health-related decision-making is necessary for health promotion both in personal and societal level.
Some environmental determinant of health are approached, and more particularly, the major problem of the origin of Emerging Infectious Diseases, in the context of the One Health Approach.

Estimated duration & relevant subjects
12 teaching hours (extended version of the scenario), organized in continuous two-hour periods if possible.
10 teaching hours (short version of the scenario).

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Designed for Biology, Science, Health Science, or Social Science classes of high school (senior high school) grades (K10-12 grades).
The Biology (or Science, or Health Science, or Social Science) teacher could cooperate with the English language teacher in order combine Science Learning with English Language Instruction, according to the Content and Language integrated learning (CLIL). In this way both scientific literacy and English fluency are promoted. The learning sequence is appropriate for this method since all the DLOs and SERs are available in English.

Content
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 courses instruction with a view to promoting active citizenship.
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.
Descriptive statistics (simple measures, indices, charts, and graphs) as a means of analyzing presenting qualitative and quantitative scientific data.
The process of an authentic scientific research and issues concerning the trustworthiness, biases, and misinterpretation of data.
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

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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, 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

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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.

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. In structured inquiry students are given the research question to-be-answered, as well as detailed step-by-step guidance of the entire process of inquiry. In guided inquiry student are only given the research question to-be-answered and the decision-making processes about the research procedure are set up to them.

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.

<u>Competences / Learning Goals</u>

Knowledge (Core Concepts)

a) Transdisciplinary concepts: Critical health literacy, public health literacy, STSE (Science, Technology, Society, Environment) interconnections, One Health approach, health disparities, health policies, empirical social research.

b) Specific content concepts: Communicable diseases, zoonoses, anthroponoses, antropozoonoses,

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emerging infectious diseases, social determinants of health, social inequities, social groups.

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.

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 organization 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.
Basic competencies of finding, comparing and evaluating pieces of information in texts.
Intermediate (or at least limited) fluency in English in case that DLOs and SERs other than the ones of the PAFSE repository are used.

School research project
Topics
What is the origin of communicable diseases?
How can an epidemic crisis affect various social groups?
How did the COVID-19 pandemic affect social groups in the local society?

I. Research management, design, and administration
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

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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 sector about educational issues) 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 the 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 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.

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Assessment methods

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

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.

Inquiry-based-learning contextualization of the scenario's digital learning objects (structured inquiry, guided inquiry, case study, argumentation, problem solving)

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Digital Learning Objects (DLOs)

DLOs created specifically for the needs of the PAFSE project

'Concept mapping about the social determinants of an epidemic'

http://photodentro.pafse.eu/handle/8586/32

'Concept map tool'

http://photodentro.pafse.eu/handle/8586/32?&locale=en

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. *'Map concerning the origin of communicable diseases'*

http://photodentro.pafse.eu/handle/8586/170

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 epidemics'*

http://photodentro.pafse.eu/handle/8586/239

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 mentioned above.

IV*. 'Health-related decision-making during an epidemic'*

http://photodentro.pafse.eu/handle/8586/240

Experiential three-part role game environment, in which the user (a pair of students) chooses a character to impersonate. 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

'Health and social inequities among European countries'

https://health-inequalities.eu/el/toolbox/interactive-map/

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)

SERs created specifically for the needs of the PAFSE project

'Conceptions about the social determinants of health and the origin of diseases'

http://photodentro.pafse.eu/handle/8586/174

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.

SERs which have been retrieved from online resources

'Health disparities during the COVID-19 pandemic'

https://www.health.org.uk/news-and-comment/charts-and-infographics/same-pandemic-unequal-impacts

Comprehensive infographic about the interconnection between health and social inequities during the

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COVID-19 pandemic.
'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.
'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.
'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).
'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.
'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).
'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. The chosen infographics highlight residence size, accessibility to the Internet and underlying health condition.
'Consequences of the COVID-19 pandemic on the society'
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.
'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.
'E-me platform H5P tools for the school project'
H5P tools of the e-me platform (https://e-me4all.eu/). By choosing 'e-me content' students can use the 'Questionnaire' tool to create the questionnaire, the 'Graph' tool to handle and present the statistical data, and the 'Accordion' tool to form the final research report.

Teaching -learning activities

Some educational activities have been framed in dotted frames, like the following one:

These activities could be seen as optional under conditions. Even though they are parts of the educational scenario, they are not inseparable ones, and they could be omitted if the teacher thinks so, mainly due to reasons relevant to restricted teaching time, limited student competences, or low student motives. This can be done according teacher's will and the omission of some framed activities does not affect the other ones, e. g., the framed activities of the 2nd, 5th, and 6th hours might be omitted, thus the framed activities of the 1st, 3rd, and 4th hours be carried hours properly. Some of the framed activities might be used as optional

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activities for more 'advances' student groups that end their task earlier than the rest, or as alternative, or optional homework for students interested.

1st teaching hour – What students think about the environmental and social determinants of an epidemic?

Learning objectives

Knowledge	Skills	Attitudes and Behaviours
-	Concept/mind mapping	Sincere self-expression

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. *The teacher could also use some news of the timeliness as engagement material to ignite students' initial interest and participation in the lesson. The teacher could distribute copies of the news to students, or could use a projector machine for the entire classroom, or students could see it in personal devices (computers or tablets) in groups.*

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 completing the concepts and connections they desire, even deleting already written concepts and connections. The graphic organizer of each student should express their own perceptions and conceptions seen under their personal point of view. It is made clear that the maps are anonymous and that they are not going to be used for grading.

If students are already familiar with the use of another concept mapping tool other than DLO I, they can use the familiar software and the guiding concepts and linkages could be written on board. Otherwise, the concept or mind map might be written on paper.

The students' data from the questionnaires and the graphical representations are collected by the teacher who shows some indicative questionnaire results anonymously to the class. The teacher shows the questions one-by-one and the frequencies 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.

The questionnaire completion and the graphic depiction of conception is suggested to be done digitally because the handling and the data collection are easier. If digital media (computers or tablets) are not easily accessible, they can be made on paper after the providence of the necessary guidance.

2nd teaching hour – Emerging Infectious Diseases and the animal origin of communicable diseases

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Learning objectives

Knowledge	Skills	Attitudes and Behaviours
Distinction between anthroponoses and zoonoses Exemplification of Emerging Infectious Diseases Identification of the settings that help the emergence of new infectious diseases	Map reading skills Handling of digital simulations	Acknowledgement of the constant issue of emergence of new infectious diseases Awareness about the modern lifestyle as a factor promoting the emergence of new infectious 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 appearance of new Emerging Infectious Diseases (seen in the framework of 'One Health' approach). DLO II is used for making this approach via structured inquiry within small groups in order to answer short scientific questions. 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, antibiotic-resistant bacterial 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, vericella, 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.

Each group is responsible for a small number of diseases (for example 3) and their work must be brief. They could be announced, in advance, the time exact limit they have (e.g. 5 minutes) for their work and the time limit to be respected.

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.

The group brainstorming is about to last just for a few minutes, for instance 5-6 minutes, and aims mainly to the students' 'unlock'. If the time is not enough for the group brainstorming, the brainstorming can be made with the whole classroom providing each student takes part in the brainstorming at least once.

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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. The video can be projected with a projector machine.

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

Learning objectives

Knowledge	Skills	Attitudes and Behaviours
Exemplification of cases of health disparities Explanation of the ways social inequities can lead to health disparities Description of the phenomenon of social determinants of health Assessment of the extent people for different social groups are expected to face health disparities Exemplification of indices showing social and health disparities	Critical and logical thinking Critical appraisal of sources of different origin Data-driven answer to questions Test of correlation between numerical indices	Acknowledgement of the global existence of health disparities Awareness about health disparities faced by vulnerable social groups Awareness about the health consequences of social inequities Acknowledgement of the existence of health disparities among European countries

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 means whether all citizens start from 'the same level' when an epidemic crisis, and a health crisis in general, happens. The critical appraisal of each source is guided by a central research question which students are told to answer according to the critical reading of the sources.

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. After studying each source, or the sum of them, a class discussion should be done to compare students' conclusions and comment on them. The educational resources that have been incorporated in DLO III are the following sources:

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

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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.
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.
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.

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 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 intrinsic features of all health crises.
Infographics SER VIII (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.
In case there are not computers or tablets available for the activity of the group analysis of the sources, the sources that are texts and infographics could be distributed to groups in print, and the videos could be shown repeatedly to the entire class with a projector machine, while the groups work on this task.
If the study tasks of each source are considered of high difficulty, or being quite time-consuming, they can be decreased if the teacher thinks so. The source iv (SER VII) has been considered as optional, because it contains more complex linguistic structure and advanced scientific terms, that could be hard to understand for some students. Its analysis might be assigned to the groups that have finished their tasks

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earlier than the other ones. During the study of the source v (SER VIII, infogrphics), each group might focus on one single infographic to save time.

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 should 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.

If time is not sufficient for the completion of the activities, the study of SER VIII (source v) can be assigned as homework, because the rest of the resources are considered to have more learning value and higher difficulty level than SER VIII.

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

Learning objectives

Knowledge	Skills	Attitudes and Behaviours
Explanation of the ways social determinants of health function Description of the effect of lifestyle of different social groups during an epidemic Exemplification of health disparities during an epidemic Explanation of the way values affect decision-making	Critical thinking Argumentation about decision-making Argumentation by referring to values Active listening and participation in discussions	Recognition and descriptions of emotions Acknowledgment of the interference of emotions at decision-making Development of empathy for different social groups Awareness about social and health disparities Recognition and identification with values Values hierarchy Development of a personal values system about social and health disparities Acknowledgement of the interference of the values system at 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

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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.

If the teacher thinks being more appropriate, only one instead of the two videos could be shown and commented, or other educational material be used, in order to recapitulate the main concepts of the previous lesson.

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 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, parameters, or guiding questions 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.

The role game aims to getting a vague approach of viewpoints that diverse people of the society have. They are not expected to reach fully realistic viewpoints, but the aim is their activation to start getting aware about the subjective realities different people in a society face. The extent to which groups are expected to focus on the topic is likely to differ according to their competences, skills, and experiences.

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.

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The classroom discussion and idea exchange phase is of the most critical since different students promote themselves the emergence of different views of social life and reality, and come across with perspectives that themselves had not even think of. Sufficient time must be given for this activity. In time that time or students' competences are not considered enough for the decision-making simulation (framed activity), this could be omitted, and 2-3 indicative decision-making questions could be addressed to the whole class, instead, in general context of awareness.

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 about 7 to 10. 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.

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 entire three-part role game could be done without using the DLO if computers or tablets are not available. Group discussions, worksheets, and group experiential games could be used, instead.

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)

Learning objectives

Knowledge	Skills	Attitudes and Behaviours
Description of the phases of an empirical social research Naming of the categories of questionnaire questions Distinction between qualitative and quantitative data	Formulation of questions appropriate for questionnaires Assessment of questions suitability for the inclusion in a research questionnaire Feedback provision Cooperation and communication	Positive reception of feedback Positive attitude towards to feedback Positive attitude towards teamwork Adoption of scientific methodology to study phenomena

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

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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.

The entire research project follows the phases, the methods, and practices of iquiry-based-learning, and more specifically the more advanced inquiry forms, in which the main subject/topic of research is defined, the research questions are either provided by the teacher (guided inquiry), or, even better, originate from students' interests (open inquiry), but the subsequent options regarding research methodology and conduct, data collection, analysis and interpretation, conclusion making, and communication, are set upon the students. In this way, students come in contact –as much as possible- with the authentic process of research, and practice higher cognitive skills of critical thinking, creative thinking, decision-making, and problem solving. In this case the research done is social, aiming to the confrontation of the common misconception, that social sciences follow totally different research methodology from physical sciences.

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. The exact research questions are defined and formulated by students themselves based on their personal interests. Students decide on the questionnaire sections, and they are divided in groups equal in number to the questionnaire sections. Each group of students is preferable comprised by 4 students, and is responsible for the study of one or two research questions, and the development and formulation of the questions for the relevant 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 overlapping, examining only one issue per question, and to include both close-ended and open-ended questions in order to allow both the free expression of the citizens (qualitative data) 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. It is important to clarify the different types of data (qualitative and quantitative) to students, and their different ways of collection, and their different function in social research, which means that qualitative data are more appropriate for free expression, and quantitative data are more appropriate for the organized study of a large amount of data.

If the teacher thinks that already-formulated questions from other questionnaires are useful, they could use some examples found on the Internet. These examples could be used in numerous ways, for instance as examples of 'good' and 'bad' cases of questions, as a practice assessment exercise of questions according to criteria, or as a source of ideas for the formulation of their own questions. If ready questions are used during the questionnaire development, they should first be subject of critical evaluation by students, otherwise students would not practice their critical thinking skills.

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.

Each questionnaire section, for which one student group is responsible, should include just a few questions, which are carefully selected and formulated, so as that the analysis of the data from the answers is easier. For example 4-6 questions (open- and close-ended questions) might be included in each section of the final questionnaire.

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. Applications such as the tools of the e-me platform (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.

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The fill-in of the questionnaires could be done anonymously by members of the local community, school, students' families,, the rest of teachers. Filled-in questionnaires must be a few in order to be easily and properly analyzed by students. For example the number of questionnaires might be about 15 to 30, depending on the number and type of questions, and students' skills. If the questionnaires gathered are much more, only a sample of them could be analyzed.

9th-10th teaching hours – Analysis of the questionnaires collected (School project)
Learning objectives

Knowledge	Skills	Attitudes and Behaviours
Distinction between qualitative and quantitative data Description of the processes of proper analysis of qualitative data Description of the processes of proper analysis of quantitative data	Proper statistical analysis of qualitative data Proper quantitative analysis of qualitative data Graph and chart creation Written description of research findings Data-driven conclusion-making Suggestion of complementary research approaches	Positive attitude towards teamwork Sincere presentation of scientific findings Keeping up research ethics (e.g. being sincere, avoidance of biases, ensuring anonymity) Adoption of scientific methodology to study phenomena

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 had been planned by the teacher and the students. The interval for the data collection has been estimated to be about a week between the 8^{th} and 9^{th} teaching hours. If participation is low, the analysis of the questionnaires could begin normally at the 9^{th} teaching hour, but also be expanded for one extra teaching hour until a sufficient number of online questionnaires has been collected. The filled-in 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 charts and graphs (e.g., histograms, bar charts, 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. At this point, a revision or introduction of some necessary elements regarding statistical analysis and graphs creation might be needed. SER XI could be used to create graphs and charts.
The data analysis should include a short description of findings in written, calculation of statistical measures, and a graph creation, (almost) for every questionnaire question. Maybe, it is better for students groups to split into subgroups of two members, and each subgroup to take responsibility of the analysis of 1-3 questionnaire questions. If a group finishes the analysis of a minimum number of questionnaires (e.g. 15 questionnaires) too early, they can go on to analyze some more questionnaires. When a subgroup finishes the analysis, they can show their results to the other members to check.
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.
The section of conclusion making is about the entire section that each group is responsible for, and not for every questionnaire question, in detail. So, it is written by the whole group. The suggestion of complementary research approaches might be difficult for some groups, and even very simple ideas are welcome.

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11th-12th teaching hours – Presentation and review of the findings of the empirical research (School project)

Learning objectives

Knowledge	Skills	Attitudes and Behaviours
Distinction among the parts of an academic research paper Distinction between data and conclusions Exemplification of factors that cause uncertainties in a social research	Presentation of scientific results Academic writing Summary making of scientific data Feedback provision Cooperation and communication	Positive attitude towards to feedback Positive attitude towards teamwork Acknowledgement of errors, uncertainties, and restrictions as integral parts of scientific research

Teaching phase according to the inquiry & project based instructional model: Completion of the project & final assessment (project presentation)

During the 11^{th} 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, issues in the sampling process 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 12^{th} 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 (SER XI can be used) 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 final research report ought to be concise and short. The Introduction and Methodology parts can be written after the consensus of all students, or 2-3 students may write a first draft on the Introduction, 2-3 students a first draft on Methodology, and, then, the whole class might agree under the coordination of the teacher. Each group may write a summary of their results and conclusion, by writing 2-3 sentences and a graph or chart for the Results section, and 1-2 sentences for the Conclusion session, that will comprise the parts of the final report, along with 3-4 general conclusion sentences agreed by the entire classroom.

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 students' work is high and the students are willing to do so, the project could be publicized in a student academic conference or journal.

Short version of the scenario (10 teaching hours)

The initial (expanded) version of the educational scenario lasts for 12 teaching hours. Difficulties that may arise due to its long duration (e.g., alignment with the Curriculum, availability of rooms, or resources). For that reason a shorter version of the scenario of 10 teaching hours is provided, which can be opted for if the teacher thinks so. The suggested modifications to the structure of the scenario are the following ones:

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Expanded version of the scenario (14 hours)	Short version of the scenario (10 hours)	Modifications
1^{st} hour	1^{st} hour	Remaining the same.
2^{nd} hour	(omitted)	The topic of this hour (environmental origin of infectious diseases) offers a complementary perspective, yet the topic remains independent from the rest of the scenario themes (social dimensions of epidemics). For this reason, it could be omitted, without having severe consequences on the whole learning sequences.
3^{th}-6^{th} hours	2^{th}-5^{th} hours	Remaining the same.
7^{th}-8^{th} hours	6^{th} hour (fusion)	The initial two-hour-session is about the development of the questionnaire, and it is considered to be summarized into a single teaching hour, after some modification be done. Each student group can be responsible for formulating only a small number of questions (e.g. 5 questions) and the phase of cross-evaluation between groups can be replaced by having the groups collaborating by two in order to come down to the final formulation of the questions. After finish of the lesson, the teacher sees the group questions, and can slightly modify the points they thinks so, they compile them to the final questionnaire, and they distribute it.
9^{th}-12^{th} hours	7^{th}-10^{th} hour	Remaining the same.

<u>Supplementary learning activities</u>

<u>I. Discussion with experts</u>

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

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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 6th or the 7th 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:

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.

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.

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

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.

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.

Academics or university professors with relevant expertise.

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:

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.

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.

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.

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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.
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

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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
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

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	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 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

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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
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

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	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

2.2.4. Social determinants of health during an epidemic/pandemic outbreak – Middle School

Main partner responsible
The Educational Approaches to Virtual Reality Laboratory (EARTH Lab), Department of Primary Education, 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.

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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 and health disparities pose a serious issue in public health promotion. Students have to be aware of this problem in order to evolve to active citizens.
The notion of health is contextualized in authentic societal settings (health policies), and an authentic way of health-related decision-making, including emotional, social, economic, and ethical factors.
The inclusion of social determinants of health in health-related decision-making is necessary for health promotion both in personal and societal level.
Some environmental determinant of health are approached, and more particularly, the major problem of the origin of Emerging Infectious Diseases, in the context of the One Health Approach.

Estimated duration & relevant subjects

12 teaching hours (extended version of the scenario), organized in continuous two-hour periods if possible.
6 teaching hours (short version of the scenario).
Designed for Biology, Science, Health Science, or Social Science classes of middle school (junior high school) grades (K9-11 grades).
The Biology (or Science, or Health Science, or Social Science) teacher could cooperate with the English language teacher in order combine Science Learning with English Language Instruction, according to the Content and Language integrated learning (CLIL). In this way both scientific literacy and English fluency are promoted. The learning sequence is appropriate for this method since all the DLOs and SERs are available in English.

Content

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 courses instruction with a view to promoting active citizenship.
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.
Descriptive statistics (simple measures, indices, charts, and graphs) as a means of analyzing presenting qualitative and quantitative scientific data.
The process of an authentic scientific research and issues concerning the trustworthiness, biases, and misinterpretation of data.
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

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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, 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

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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 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. In structured inquiry students are given the research question to-be-answered, as well as detailed step-by-step guidance of the entire process of inquiry. In guided inquiry student are only given the research question to-be-answered and the decision-making processes about the research procedure are set up to them.

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

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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.

<u>Competences / Learning Goals</u>
Knowledge (Core Concepts)
a) Transdisciplinary concepts: Critical health literacy, public health literacy, STSE (Science, Technology, Society, Environment) interconnections, One Health approach, health disparities, health policies, empirical social research.
b) Specific content concepts: Communicable diseases, zoonoses, anthroponoses, antropozoonoses, emerging infectious diseases, social determinants of health, social inequities, social groups.

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.

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.

<u>Classroom organization requirements</u>
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.

<u>Prerequisite knowledge and skills</u>
Existence of communicable diseases capable of leading to pandemic and epidemic outbreaks.

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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.
Basic competencies of finding, comparing and evaluating pieces of information in texts.
Intermediate (or at least limited) fluency in English in case that DLOs and SERs other than the ones of the PAFSE repository are used.

School research project
Topics
What is the origin of communicable diseases?
How can an epidemic crisis affect various social groups?
How did the COVID-19 pandemic affect social groups in the local society?

I. Research management, design, and administration
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 sector about educational issues) 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 the 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

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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 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 methods

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.

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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
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.
Inquiry-based-learning contextualization of the scenario's digital learning objects (structured inquiry, guided inquiry, case study, argumentation, problem solving)

Digital Learning Objects (DLOs)
DLOs created specifically for the needs of the PAFSE project
'Concept mapping about the social determinants of an epidemic'
http://photodentro.pafse.eu/handle/8586/32
'Concept map tool'
http://photodentro.pafse.eu/handle/8586/32?&locale=en
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. *'Map concerning the origin of communicable diseases'*
http://photodentro.pafse.eu/handle/8586/170
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 epidemics'*
http://photodentro.pafse.eu/handle/8586/239
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 mentioned above.
IV*. 'Health-related decision-making during an epidemic'*
http://photodentro.pafse.eu/handle/8586/240
Experiential three-part role game environment, in which the user (a pair of students) chooses a character to impersonate. 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

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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

'Health and social inequities among European countries'

https://health-inequalities.eu/el/toolbox/interactive-map/

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)

SERs created specifically for the needs of the PAFSE project

'Conceptions about the social determinants of health and the origin of diseases'

http://photodentro.pafse.eu/handle/8586/174

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.

SERs which have been retrieved from online resources

'Health disparities during the COVID-19 pandemic'

https://www.health.org.uk/news-and-comment/charts-and-infographics/same-pandemic-unequal-impacts

Comprehensive infographic about the interconnection between health and social inequities during the COVID-19 pandemic.

'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.

'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).

'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.

'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).

'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. The chosen infographics highlight residence size, accessibility to the Internet and underlying health condition.

'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.

'E-me platform H5P tools for the school project'

H5P tools of the e-me platform (https://e-me4all.eu/). By choosing 'e-me content' students can use the 'Questionnaire' tool to create the questionnaire, the 'Graph' tool to handle and present the statistical data,

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and the 'Accordion' tool to form the final research report.

Teaching -learning activities

Some educational activities have been framed in dotted frames, like the following one:

These activities could be seen as optional under conditions. Even though they are parts of the educational scenario, they are not inseparable ones, and they could be omitted if the teacher thinks so, mainly due to reasons relevant to restricted teaching time, limited student competences, or low student motives. This can be done according teacher's will and the omission of some framed activities does not affect the other ones, e. g., the framed activities of the 2nd, 5th, and 6th hours might be omitted, thus the framed activities of the 1st, 3rd, and 4th hours be carried hours properly. Some of the framed activities might be used as optional activities for more 'advances' student groups that end their task earlier than the rest, or as alternative, or optional homework for students interested.

1st teaching hour – What students think about the environmental and social determinants of an epidemic?

Learning objectives

Knowledge	Skills	Attitudes and Behaviours
-	Mind mapping	Sincere self-expression

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. *The teacher could also use some news of the timeliness as engagement material to ignite students' initial interest and participation in the lesson. The teacher could distribute copies of the news to students, or could use a projector machine for the entire classroom, or students could see it in personal devices (computers or tablets) in groups.*

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. Mind map are easier to be made and understood for middle school students than concept maps, especially if they have limited previous experience with concept maps. Advanced students can easily turn their mind maps into concept maps by writing verbs above the linkages. 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 completing the concepts and connections they desire, even deleting already written concepts and connections. The graphic organizer of each student should express their own perceptions and conceptions seen under their personal point of view. It is made clear that the maps are anonymous and that they are not going to be used for grading.

If students are already familiar with the use of another mind mapping tool other than DLO I, they can use the familiar software and the guiding concepts and linkages could be written on board. Otherwise, the concept or mind map might be written on paper.

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The students' data from the questionnaires and the graphical representations are collected by the teacher who shows some indicative questionnaire results anonymously to the class. The teacher shows the questions one-by-one and the frequencies 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.
The questionnaire completion and the graphic depiction of conception is suggested to be done digitally because the handling and the data collection are easier. If digital media (computers or tablets) are not easily accessible, they can be made on paper after the providence of the necessary guidance.

2nd teaching hour – Emerging Infectious Diseases and the animal origin of communicable diseases
Learning objectives

Knowledge	Skills	Attitudes and Behaviours
Distinction between anthroponoses and zoonoses Exemplification of Emerging Infectious Diseases Identification of the settings that help the emergence of new infectious diseases	Map reading skills Handling of digital simulations	Acknowledgement of the constant issue of emergence of new infectious diseases Awareness about the modern lifestyle as a factor promoting the emergence of new infectious 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 appearance of new Emerging Infectious Diseases (seen in the framework of 'One Health' approach). DLO II is used for making this approach via structured inquiry within small groups in order to answer short scientific questions. 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, antibiotic-resistant bacterial 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, vericella, 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.
Each group is responsible for a small number of diseases (for example 3) and their work must be brief. They could be announced, in advance, the time exact limit they have (e.g. 5 minutes) for their work and the time limit to be respected.
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

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population map as complements to the map of epidemic origins. They conclude that 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.
The group brainstorming is about to last just for a few minutes, for instance 5-6 minutes, and aims mainly to the students' 'unlock'. If the time is not enough for the group brainstorming, the brainstorming can be made with the whole classroom providing each student takes part in the brainstorming at least once.
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. The video can be projected with a projector machine.

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

Learning objectives

Knowledge	**Skills**	**Attitudes and Behaviours**
Exemplification of cases of health disparities Explanation of the ways social inequities can lead to health disparities Description of the phenomenon of social determinants of health Assessment of the extent people for different social groups are expected to face health disparities	Critical and logical thinking Critical appraisal of sources of different origin Data-driven answer to questions	Acknowledgement of the global existence of health disparities Awareness about health disparities faced by vulnerable social groups Awareness about the health consequences of social inequities Acknowledgement of the existence of health disparities among European countries

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 means whether all citizens start from 'the same level' when an epidemic crisis, and a health crisis in general, happens. The critical appraisal of each source is guided by a central research question which students are told to answer according to the critical reading of the sources.
Students work in groups following their worksheets and studying successively four 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

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the general research question posed to the students. After studying each source, or the sum of them, a class discussion should be done to compare students' conclusions and comment on them. The educational resources that have been incorporated in DLO III are the following sources:

The first video of DLO III will not be used, because of the high level of English fluency needed. Instead of watching the video, students are engaged in an introductory classroom discussion with the following topic. 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.

Video SER IV (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. 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.

Public health organization text SER V (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. The guiding inquiry question of the study of this text is the same with the previous one but requires much greater degree of analysis.

Academic text SER VI (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 generalize and conceptualize the notion of social determinants of health by using their own examples and attempting to formulate a 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 intrinsic features of all health crises.

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.

In case there are not computers or tablets available for the activity of the group analysis of the sources, the sources that are texts and infographics could be distributed to groups in print, and the videos could be shown repeatedly to the entire class with a projector machine, while the groups work on this task.

If the study tasks of each source are considered of high difficulty, or being quite time-consuming, they can be decreased if the teacher thinks so. The source iv (SER VII) has been considered as optional, because it contains more complex linguistic structure and advanced scientific terms, that could be hard to understand for some students. Its analysis might be assigned to the groups that have finished their tasks

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earlier than the other ones. During the study of the source v (SER VII, infographics), each group might focus on one single infographic to save time.

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 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 should 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 VI (v) can be assigned as homework, as the other activities are estimated to have more educational benefits, yet greater degree of difficulty.

If time is not sufficient for the completion of the activities, the study of SER VII (source v) can be assigned as homework, because the rest of the resources are considered to have more learning value and higher difficulty level than SER VII.

The study of either SER VI or DLO V should be included in the scenario, since they need more advanced critical thinking, logical thinking and argumentation skills than the other resources and, moreover, draw a broader framework of social determinants of health more than the COVID-19 pandemic, or communicable diseases, in general.

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

Learning objectives

Knowledge	Skills	Attitudes and Behaviours
Explanation of the ways social determinants of health function Description of the effect of lifestyle of different social groups during an epidemic Exemplification of health disparities during an epidemic Explanation of the way values affect decision-making	Critical thinking Argumentation about decision-making Argumentation by referring to values Active listening and participation in discussions	Acknowledgment of the interference of emotions at decision-making Development of empathy for different social groups Awareness about social and health disparities Recognition and identification with values Values hierarchy Development of a personal values system about social and health disparities

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 video

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SER VIII might be shown and commented in a classroom discussion. It is appropriate for the clarification of misunderstandings and strengthening meaningful conceptual understanding of the notion of social determinants of health.

If the teacher thinks being more appropriate, only one instead of the two videos could be shown and commented, or other educational material be used, in order to recapitulate the main concepts of the previous lesson.

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 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, parameters, or guiding questions 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.

The role game aims to getting a vague approach of viewpoints that diverse people of the society have. They are not expected to reach fully realistic viewpoints, but the aim is their activation to start getting aware about the subjective realities different people in a society face. The extent to which groups are expected to focus on the topic is likely to differ according to their competences, skills, and experiences.

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 large extent 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.

The classroom discussion and idea exchange phase is of the most critical since different students promote

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themselves the emergence of different views of social life and reality, and come across with perspectives that themselves had not even think of. Sufficient time must be given for this activity. In time that time or students' competences are not considered enough for the decision-making simulation (framed activity), this could be omitted, and 2-3 indicative decision-making questions could be addressed to the whole class, instead, in general context of awareness.

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 about 7 to 10. 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.

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 quite divergent personal behaviours and policy making during an epidemic. The interconnection among values, attitudes, decision making, and behaviours is also highlighted.

The entire three-part role game could be done without using the DLO if computers or tablets are not available. Group discussions, worksheets, and group experiential games could be used, instead.

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)

Learning objectives

Knowledge	Skills	Attitudes and Behaviours
Description of the phases of an empirical social research Distinction between qualitative and quantitative data	Formulation of questions appropriate for questionnaires Assessment of questions suitability for the inclusion in a research questionnaire Feedback provision Cooperation and communication	Positive reception of feedback Positive attitude towards to feedback Positive attitude towards teamwork Adoption of scientific methodology to study phenomena

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

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pandemic. The 7th and 8th teaching hours focus on the design of the social research tool, which is a questionnaire.
The entire research project follows the phases, the methods, and practices of iquiry-based-learning, and more specifically the more advanced inquiry forms, in which the main subject/topic of research is defined, the research questions are either provided by the teacher (guided inquiry), or, even better, originate from students' interests (open inquiry), and the subsequent steps regarding research methodology and conduct, data collection, analysis and interpretation, conclusion making, and communication, are given by the teacher. However the guidance is given in the form of general directions, principles, phases, and techniques, and not in the form of a step-by-step guide. In this way, students come in contact –as much as possible- with the authentic process of research, and practice higher cognitive skills of critical thinking, creative thinking, decision-making, and problem solving. In this case the research done is social, aiming to the confrontation of the common misconception, that social sciences follow totally different research methodology from physical sciences.
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. The exact research questions are defined and formulated by students themselves based on their personal interests. The exact questionnaire sections are defined by the teacher so as to be equal in number with the student groups. Each group of students is preferably comprised by 4 students, and is responsible for the study of one research question, and the development and formulation of the questions for the relevant questionnaire section.
Each group takes responsibility of coming up with and formulating the questions to fill in the assigned section. They are urged to choose explicit and meaningful questions without overlapping, examining only one issue per question, and to include both close-ended and open-ended questions in order to allow both the free expression of the people (qualitative data) 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. It is important to clarify the different types of data (qualitative and quantitative) to students, and their different ways of collection, and their different function in social research, which means that qualitative data are more appropriate for free expression, and quantitative data are more appropriate for the organized study of a large amount of data.
If the teacher thinks that already-formulated questions from other questionnaires are useful, they could use some examples found on the Internet. These examples could be used in numerous ways, for instance as examples of 'good' and 'bad' cases of questions, as a practice assessment exercise of questions according to criteria, or as a source of ideas for the formulation of their own questions. If ready questions are used during the questionnaire development, they should first be subject of critical evaluation by students, otherwise students would not practice their critical thinking skills.
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.
Each questionnaire section, for which one student group is responsible, should include just a few questions, which are carefully selected and formulated, so as that the analysis of the data from the answers is easier. For example 4-6 questions (open- and close-ended questions) might be included in each section of the final questionnaire.
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. Applications such as the tools of the e-me platform (SER IX) 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.

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The fill-in of the questionnaires could be done anonymously by members of the local community, school, students' families, the rest of teachers. Filled-in questionnaires must be a few in order to be easily and properly analyzed by students. For example, the number of questionnaires might be about 10 to 20, depending on the number and type of questions, and students' skills. If the questionnaires gathered are much more, only a sample of them could be analyzed.

9th-10th teaching hours – Analysis of the questionnaires collected (School project)

Learning objectives

Knowledge	Skills	Attitudes and Behaviours
Distinction between qualitative and quantitative data Description of the processes of proper analysis of qualitative data Description of the processes of proper analysis of quantitative data	Proper statistical analysis of qualitative data Proper quantitative analysis of qualitative data Graph and chart creation Written description of research findings Data-driven conclusion-making	Positive attitude towards teamwork Sincere presentation of scientific findings Keeping up research ethics (e.g. being sincere, avoidance of biases, ensuring anonymity) Adoption of scientific methodology to study phenomena

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 had 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 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 charts and graphs (e.g., histograms, bar charts, 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.

At this point, a detailed course on the necessary elements of statistical analysis, graph creation revision or introduction of some necessary elements regarding statistical analysis and graphs creation is necessary. This introduction might include some of the following ones: the distinction of quantitative and qualitative data, the creation of histograms, bar charts, pie charts, and scatter plots, the calculation of absolute and relative frequencies, the calculation of mean, range, and media, and the identification of common or repetitive themes in qualitative data. SER IX, or some other relevant software, could be used to create graphs and charts.

The data analysis should include a short description of findings in written, calculation of statistical measures, and a graph creation, (almost) for every questionnaire question. Maybe, it is better for students groups to split into subgroups of two members, and each subgroup to take responsibility of the analysis of 1-3 questionnaire questions. If a group finishes the analysis of a minimum number of questionnaires (e.g. 8 questionnaires) too early, they can go on to analyze some more questionnaires. When a subgroup finishes the analysis, they can show their results to the other members to check.

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

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would shed more light on the research if possible.
The section of conclusion making is about the entire section that each group is responsible for, and not for every questionnaire question, in detail. So, it is written by the whole group. The suggestion of complementary research approaches might be difficult for some groups, and even very simple ideas are welcome.

<u>11th-12th teaching hours – Presentation and review of the findings of the empirical research (School project)</u>

Learning objectives

Knowledge	Skills	Attitudes and Behaviours
Distinction between data and conclusions Exemplification of factors that cause uncertainties in a social research	Presentation of scientific results Summary making of scientific data Feedback provision Cooperation and communication	Positive attitude towards to feedback Positive attitude towards teamwork Acknowledgement of errors, uncertainties, and restrictions as integral parts of scientific research

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 a 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, issues during the sampling process 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 organize this final report (SER IX can be used) 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 teacher's guidance is decisive during this process, since students tend to confuse results with conclusions. This distinction must be made quite clear. It is a very important in component of scientific literacy and scientific competencies since it illustrates the deep Nature of Science distinction between facts and assumptions.

The final research report ought to be concise and short. The Introduction and Methodology parts can be written after the consensus of all students, or 2-3 students may write a first draft on the Introduction, 2-3 students a first draft on Methodology, and, then, the whole class might agree under the coordination of the teacher. Each group may write a summary of their results and conclusion, by writing 2-3 sentences and a graph or chart for the Results section, and 1-2 sentences for the Conclusion session, that will comprise the parts of the final report, along with 3-4 general conclusion sentences agreed by the entire classroom.

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 students' work is high and the students are willing to do so, the project could be publicized

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in a student academic conference or journal.

Short version of the scenario (6 teaching hours)
The initial (expanded) version of the educational scenario lasts for 12 teaching hours. Difficulties that may arise due to its long duration (e.g. alignment with the Curriculum, availability of rooms, or resources). For that reason a shorter version of the scenario of 10 teaching hours is provided, which can be opted for if the teacher thinks so. The suggested modifications to the structure of the scenario are the following ones:

Expanded version of the scenario (14 hours)	Short version of the scenario (6 hours)	Modifications
1st, 3rd, 4th hour	1st – 2nd hours (fusion)	The content of these hours are rearranged. The session begins with the student completing in pairs the mind map, in order to be engaged in the topic. A short classroom discussion on students' ideas takes place, and the classroom discussion about the cases cleaner, open market seller and office worker takes places. Students work in groups on the SERs IV, V in DLO III. Then, the teacher chooses one of the SER VI, SER VII, or DLO V in order to deepen with the students in one of the three perspectives.
2nd hour	(omitted)	The topic of this hour (environmental origin of infectious diseases) offers a complementary perspective, yet the topic remains independent from the rest of the scenario themes (social dimensions of epidemics). For this reason, it could be omitted, without having severe consequences on the whole learning sequences.
5th-6th hours	3rd hour (fusion)	Students are important to get involved in the role game in order to acknowledge the complex and often non-reasonable nature of decision making.
7th-8th hours	4th hour (fusion)	The initial two-hour-session is about the development of the questionnaire, and it is considered to be summarized into a single teaching hour, after some modification be done. The topic, the research questions and the sections of the questionnaire are defined by the teacher. Each student group can be responsible for formulating only a small number of questions (e.g. 5 questions) and the phase of cross-evaluation between groups can be replaced by having the groups collaborating by two in order to come down to the final formulation of the questions. After finish of the lesson, the teacher examines the group questions, and can slightly modify the points they thinks so, they compile them to the final questionnaire, and they distribute it.
9th-11th hours	5th-6th hour (fusion)	Each student group is assigned to analyze a small number of questionnaires (e.g. 8 questionnaires) in

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		order to save time. For the same reason, detailed worksheets are given to students in order to guide them during data analysis. The steps of data analysis can be aligned to be the practice of the statistical technique shown just the moment before. Students briefly present their conclusions to the classroom (about 2-4 sentences per group), and the teacher notes them down on the whiteboard. Then scaffolds the students to draw the final general conclusion of the entire study. The worksheets are collected and assessed.
12th hour	(omitted)	The part of the final report writing is omitted, since it is not a vital part of the learning sequence and the inquiry process, when aiming to middle school students. However, it could be assigned as an optional project for students with strong STEM interest, who might be quite beneficial for.

<u>Supplementary learning activities</u>

<u>I. Discussion with experts</u>

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.

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 6th or the 7th 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:

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

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of the emergence of new infectious diseases.
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.
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
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.
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.
Academics or university professors with relevant expertise.
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:
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.
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.
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.
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.
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

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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
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

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	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 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

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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

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	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
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

2.2.5. Cognitive and affective determinants of health during an epidemic/pandemic outbreak for students with Intellectual Disabilities

Main partner responsible
The Educational Approaches to Virtual Reality Technologies laboratory (EARTH lab), University of Ioannina, Greece

<u>Overview / Context</u>
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.

<u>Estimated duration</u>
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.

<u>Scientific content and its relevance to public health education</u>
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 behavior (social distancing).

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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.

Content

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

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).
Infectious Diseases: can be transmitted from one person to another. They are caused by pathogens such as viruses, bacteria, fungi and protozoa.
Pathogenic: the microorganism that enters a person and causes him a disease.
Host: the person being infected.
Infection: the entry of a pathogenic microorganism into a host.
Transmissibility: the ability to transmit a pathogen from an infected person to a healthy one.
Incubation period: the time interval between infection and the onset of the first symptoms of the disease.
Epidemic: the large number of cases of a disease in a given period of time.
Pandemic: the spread of the disease in many countries
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).
Quarantine: restricting movement and contact in people considered to be infected with a contagious disease.

Pedagogical glossary

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.
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.
Prompting: the provision of partial assistance incorporates appropriate stimuli and their management during teaching.
Single subject design: is an experimental research design that studies the student's self-performance over time.
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.
Models in science education: concern selective representations of the natural world with the aim of better

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understanding by students.
Simulations: digital representation of functions, processes and phenomena with an educational character. Usually, the simulations cannot be performed in physical conditions for practical reasons.

Competences / Learning Goals

Knowledge

Infectious diseases, virus, epidemic/pandemic, virus, symptoms, diagnosis, prevention, social behavior, intellectual disabilities, scientific literacy, health literacy, STEM, STSE.

Skills

General: inquiry skills (identify relations between variables, describe thinking process, data as evidence, assessment, discussion and communication), scientific content questions engagement, collect data
Students' profile:
The target group enrolls 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 behavior 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.

Attitudes (Affective domain)

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 behavior standards

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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.
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 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?

School research project

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.
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.

Assessment methods
Initial assessment of prior knowledge and attitudes of students (baseline phase).

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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.
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 foster teachers' skill sets regarding single case research designs integrating DLOs in inquiry activities

Digital learning objects
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.

Supplementary educational resources for further development
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)

Teacher-learning activities
Principal target

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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.
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

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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?)
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?

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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.

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?

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Indicative literature

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Assessment Questionnaire- Knowledge, Skills, Beliefs, attitudes and behavior

cenario on the 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 defense/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	
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.

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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. **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

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	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

2.2.6. Function of vaccines, vaccination hesitancy and misinformation – High School

Main partner responsible
The Educational Approaches to Virtual Reality Lab (EARTH Lab), Department of Primary Education, 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

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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 an act 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.
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 (extended version of the scenario) organized in continuous two-hour periods if possible.
10 teaching hours (short version of the scenario).
Designed for Biology or Health Sciences classes of high school (senior high school) grades (K10-12 grades).
The scenario might also be applicable for a unified Science syllabus.
The Biology (or Health Sciences, or Science) teacher could cooperate with the English language teacher in order to combine Science Learning with English Language Instruction, according to the Content and Language integrated learning (CLIL). In this way both scientific literacy and English fluency are promoted.

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The learning sequence is appropriate for this method since all the DLOs and SERs are available in English

Content
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 and interpretation 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 (science communication).
STEM education for the confrontation of a crucial contemporary phenomenon with devastating consequences to public health (vaccine hesitancy).

Content glossary
Adaptive or specific 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 the Alzheimer's disease.
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

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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 or nonspecific 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.
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.
Recombinant 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

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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.
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. In structured inquiry students are given the research question to-be-answered, as well as

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detailed step-by-step guidance of the entire process of inquiry. In guided inquiry student are only given the research question to-be-answered and the decision-making processes about the research procedure are set up to them'

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.

'Problem solving: The problem solving approach includes students groups practicing higher thinking skills and making decisions in to analyze a given problem and propose solutions to it. At first, the problem settings are described to students along with the desirable aim, and some basic limitations. Each groups analyzes the problem and comes up with as more and as diverse solutions possible (creative thinking), and then evaluates these ideas (critical thinking) through group discussions, pros and cons comparisons, assessment according to criteria, pilot tests, tests, or other ways, and come down to a final proposed solution, as detailed as possible. After testing the proposed solution, or getting feedback on it, the group might have to repeat the steps of improve the solution'.

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.

<u>Competences / Learning goals</u>

Knowledge (Core Concepts)

a) Transdisciplinary concepts: Critical health literacy, public health literacy, pseudoscience and misinformation, scientific numeracy, science communication and journalism.

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, recombinant 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.

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.

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

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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.
Intermediate, or at least limited, fluency in English in case that DLOs and SERs other than the ones of the PAFSE repository are used.

School research project

Topics

How do vaccines protect me from infectious diseases?
How does vaccination protect public health?
How can I identify a text of medical misinformation?
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.

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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.
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 methods
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

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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.
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 instruction 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.
Inquiry-based-learning contextualization of the scenario's digital learning objects (structured inquiry, guided inquiry, case study, argumentation, problem solving).
The use of graphic organizers, such as the KWL tables and concept maps, in instruction.
Teaching of critical reading and recognizing 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.
Ways to handle controversial socioscientific issues in the classroom.

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Digital Learning Objects (DLOs)

DLOs created specifically for the needs of the PAFSE project

'Table of the learning procedure about vaccines'

http://photodentro.pafse.eu/handle/8586/50

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.

'Mechanisms of specific immune response'

http://photodentro.pafse.eu/handle/8586/242

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.

'Concept map about the immune response'

http://photodentro.pafse.eu/handle/8586/148

Semi-structured concept map concerning the main points of immune response.

'Function of vaccine types'

http://photodentro.pafse.eu/handle/8586/172

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.

'Concept map about vaccines'

http://photodentro.pafse.eu/handle/8586/157

Semi-structured concept map concerning the main points of vaccine function and types.

'Parameters affecting herd immunity'

http://photodentro.pafse.eu/handle/8586/171

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.

'Timeline of smallpox'

http://photodentro.pafse.eu/handle/8586/243

Timeline of the evolution and eradication of smallpox, including ancient references to the disease, historical epidemics and pandemics, the development of the first vaccines against it, the implementation of mass vaccination programmes, and the total eradication of the disease.

'Vaccine efficacies and adverse effects'

http://photodentro.pafse.eu/handle/8586/160

Visualization of vaccine efficacies and the frequencies 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.

'Information and misinformation about vaccination'

http://photodentro.pafse.eu/handle/8586/241

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.

DLOs which have been retrieved from online resources

'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.

'Types of viruses'

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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.
'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.
'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.
'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)
SERs created specifically for the needs of the PAFSE project
'Conceptions about microbes, immunity, and vaccines'
http://photodentro.pafse.eu/handle/8586/173
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.
SERs which have been retrieved from online resources
'The importance of vaccination'
https://www.cdc.gov/globalhealth/socialmedia/cards/images/2-3million_fb_ig.jpg
Infographic by the Center for Disease Control and Prevention highlighting the importance of vaccination by using numerical data.
'Polio eradication'
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.
'Vaccination against the pneumoniococcus'
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.
'Main categories of pathogens'
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).
'Diversity of pathogens'
https://www.nationalgeographic.org/media/infectious-agents/
Educational infographic by National Geographic concisely presenting the main kinds of pathogens.
'Microorganism scale'
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).
'Bacterial diversity'

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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.
'Macrophage phagocytosis'
https://www.youtube.com/watch?v=BlPlgGbb2IU
YouTube video showing the phagocytosis of bacteria by a macrophage as captured with an optical microscope.
'How vaccines work'
https://www.youtube.com/watch?v=-muIoWofsCE
Educational YouTube video by the channel Oxford VaccineGroup regarding the way vaccines work.
'Vaccines against COVID-19'
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.
'What herd immunity is'
https://www.youtube.com/watch?v=XJFoOCmJsdg
Educational YouTube visualization video presenting the mechanism behind herd immunity.
'World's deadliest pandemics'
https://www.weforum.org/agenda/2020/03/a-visual-history-of-pandemics
Infographic illustrating the deadliest pandemics in the history of humanity.
'Word frequency over time'
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.
'Measles outbreaks and vaccine coverage'
https://fred.publichealth.pitt.edu/measles
Simulation showing the emergence of measles outbreaks in USA cities in the case where vaccination coverage would fail.
'Misinformation about vaccine adverse effects'
https://www.youtube.com/watch?v=zBkVCpbNnkU
Educational YouTube video by the channel Kurzgesagt about the degree of danger vaccine adverse effects have.
'E-me platform H5P tools for the school project'
H5P tools of the e-me platform (https://e-me4all.eu/). By choosing 'e-me content' students can use the 'Course Presentation' tool to create an interactive and multimodal presentation promoting vaccination, including texts, images, videos, short questions, etc, for the health promotion campaign, and the 'Interactive Book' to write an interactive and multimodal guide against vaccination, having the same technical potential, as well.

Teacher-learning activities
Some educational activities have been framed in dotted frames, like the following one:

These activities could be seen as optional under conditions. Even though they are parts of the educational scenario, they are not inseparable ones, and they could be omitted if the teacher thinks so, mainly due to reasons relevant to restricted teaching time, limited student competences, or low student motives. This can be done according teacher's will and the omission of some framed activities does not affect the other ones, e. g. the framed activities of the 2nd, 5th, and 6th hours can be omitted, thus the framed activities of the 1st, 3rd, and 4th hours be carried hours properly. Some of the framed activities might be used as optional activities for more 'advances' student groups that end their task earlier than the rest, or as alternative, or optional homework for students interested.

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1st teaching hour – Is it important to learn about vaccination?

Learning objectives

Knowledge	Skills	Attitudes and Behaviours
-	Recall of previous knowledge	Interest about vaccination-related topics Expression of expectation from the learning sequence

Teaching phase according to the inquiry & project based instructional model: Engagement – Externalization of students' initial conceptions

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 15 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:

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.

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.

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.

The interactive map (DLO X) 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.

The suggested educational resources above are indicative. There is no need to use all of them. The teacher selects which resources are thought to be more appropriate to enhance the teaching process, and utilizes them. Educational resources other than these might also be used if the teacher would like so. It is estimated that 2-3 educational resources might be enough. They can be shown with a projector machine, or some of them could be distributed in print.

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.

In order to have students use DLO I, the teach must previously have been signed in to the platform https://mathspace.gr/pafse/index.php?signIn=1l, and then enter all students one-to-one so that personal passwords are issued for each of them. These passwords are needed for each students to enter the DLO I and submit their answers. Otherwise, a printed version of the KWL table could be distributed.

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2nd teaching hour – Variety, structure and life cycle of microorganisms

Learning objectives

Knowledge	Skills	Attitudes and Behaviours
Naming the main categories of pathogens Description of the mechanism bacteria cause damage to humans Description of the mechanism viruses cause damage to humans Comparison of the sizes of bacteria, viruses, and human cells Description of the basic viruses structure Vague description of viruses reproduction Comparison and contrast of bacteria and viruses	Recognition of visual represantetions bacteria and viruses Handling of digital simulations	-

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.

Infographic SER VI might be unsuitable or too time-consuming for certain students or classes because of the large load of information it has, or the advanced use of English (including advanced scientific terms).

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.

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 XI. 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 IX and compare them to one another concerning their morphology and anatomy, their hosts, and their genetic material.

Students do not have to use the explanatory texts of DLO XI in detail, which might be too hard for their level of conceptual understanding, nor do they have to focus on the details of the diagrammatic

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representations of virus life cycles. It is suggested to scaffold students with a worksheet that guides them to answer shortly some very specific questions concerning the virus name, the disease name, the host, the virus structure (protein capsid and lipid envelope), the virus dimensions, and the type of genetic material. No detailed knowledge on life cycles or high fluency in English are needed to detect these pieces of information.

3rd teaching hour – The elements of the adaptive immune response

Learning objectives

Knowledge	**Skills**	**Attitudes and Behaviours**
Distinction of adaptive (specific) and innate (nonspecific) immunity Description of the basic stages of the immune response against a bacterial infection Description of the basic stages of the immune response against a viral infection Explanation of the roles of memory cells and antibodies Definition of primary and secondary immune response Comparison and contrast of primary and secondary immune response	Handling of digital simulations Graph intepretation Concept mapping	-

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 or specific immunity and the differences between primary and secondary immune response.

The immunity concepts and processes included in the simulation are much more than the basic concepts and processes that the ones included in the learning objectives. This is done in the service of a fuller and more concrete conceptual understanding, especially for students showing a more intense interest in the topic. The main points that the lesson, and the learning objectives, focus on are the differences between innate (nonspecific) and adaptive (specific) immunity, the differences of primary and secondary immune response regarding the rate or the response and the quantity of antibodies produced, the fact that the secondary immune response lays at the work of memory cells, and the nature and role of antibodies, meaning they are acellular substances of limited life span, and at no case the same with the entire immune system.

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 X 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

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recapitulation.
It is suggested not to focus on the names of the immune cell types during the instruction, but to put emphasis on their roles, instead. Specific mentions must be made on the function of the memory cells and the antibodies.
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.
A graph showing primary and secondary immune responses is a visual way of representing their function and differences, and may be helpful for some students to better understanding their differences regarding the response rate and quantity of antibodies, therefore.
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.
The concept map is complex and includes several empty frames (concepts), needing therefore sufficient time for its completion. If time is not enough, it can be an activity only for student groups having finished their work earlier than the others. Otherwise some the answers for some empty frames may be given to students as hints, as a means to make the completion of the concept map easier, depending on the points the teacher thinks to be more difficult, or has highlighted, or not highlighted, during the instruction,

4th teaching hour – Types and function of vaccines

Learning objectives

Knowledge	Skills	Attitudes and Behaviours
Explanation of the way vaccines work Argumentation for the use of vaccines as a means of disease prevention Naming of different vaccine types Description of different vaccine types Comparison and contrast of different vaccine types.	Discussion on scientific topics Argumentation and decision-making Cooperation and communication Handling of digital simulations Concept mapping	Appreciation of vaccines for their services to personal health Appreciation of vaccines for their services to disease prevention Acknowledgement of the interaction between science and technology

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 IX 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

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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:

Live-attenuated pathogen vaccines.

Inactivated pathogen vaccines.

Recombined microorganism vaccines / viral vector vaccines.

DNA vaccines.

RNA vaccines.

Protein subunit vaccines.

Virus-like protein (VLP) vaccines

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, some of which may be utilized during the lesson, are the following ones:

A highly infectious bacterium which produces harmful protein toxins.

A bacterium causing a very severe disease, and for that reason the development of the strongest immune response possible is preferable.

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).

A highly infectious and dangerous bacterium with characteristic protein structures on its surface.

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.

A very dangerous DNA virus with well-studied structure and genome.

A very dangerous RNA virus with well-studied structure and genome.

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.

A novel very dangerous virus which can be easily handled in the laboratory.

A virus which mutates at a very high rate.

A very contagious and dangerous virus, which is a variant of an already existing virus with very low infectivity.

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).

The pathogen cases above are indicative. Each student group could work on 4-6 cases, different for each group, for time-saving reasons. During the classroom discussion following, students having worked on the same cases argue on their choices.

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.

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The video about the COVID-19 vaccines is optional, but is suggested on the grounds of students' interest on the topics, since COVID-19 vaccines had dominated the public discourse about science during the COVID-19 pandemic (e.g. mRNA vaccines). Alternatively, the time could be used for the completion of the concept map, instead of the video.
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.
The concept map is complex and includes several empty frames (concepts), needing therefore sufficient time for its completion. If time is not enough, it can be an activity only for student groups having finished their work earlier than the others. Otherwise some the answers for some empty frames may be given to students as hints, as a means to make the completion of the concept map easier, depending on the points the teacher thinks to be more difficult, or has highlighted, or not highlighted, during the instruction,

5th teaching hour – How different parameters affect the achievement of herd immunity
Learning objectives

Knowledge	Skills	Attitudes and Behaviours
Explanation of how herd immunity works Argumentation for the vaccination-serviced protection of unvaccinated people Explanation of how disease transmissibility, vaccine efficacy, and vaccine coverage affect herd immunity Argumentation for the need of ensuring broad vaccine coverage of a population Distinction between dependent and independent variables	Testing as a way to answer research questions Modification of variables to carrying out tests Data collection and analysis Data-driven conclusion-making Graph creation Graph intepretation Argumentation and discussion concerning scientific topics Handling of digital simulations	Appreciation of vaccines for their services to public health Acknowledgement of the effect of personal decision-making to the society Acknowledgement of the effect of the collective behavior to each person Consideration of vaccination as a solidarity action Awareness about the value of vaccination Adoption of experimentation as a way of examining the natural world

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 teacher is suggested to address some questions to the classroom as an engagement activity. These questions could be whether it is meaningful for one to get vaccinated supposed 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 addresses 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 duration of the disease. Other variables which might have been expressed (e.g., citizens' social behavior, application of hygiene rules, the existence of already-immune population from past infections, spatial or geographical distribution of vaccination coverage etc.) although being completely important as well, are

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not going to be tested during this inquiry process.
The distinction between dependent and independent variables during an experiment or test, seems to be useful for this activity. It is also important to clarify that a experiment or test to study a research question, it is important to try to ensure that only one independent variable is modified per test, the one the effect of which on the dependent variables one wants to examine. The other independent variables should remain as stable as possible, in order to get comparable results.
The activities of this hour include the 'experimental' test of one research question per time. It would be useful to have worksheets guiding students to their 'experimental' work. For each inquiry process, there should in include a clearly formulated question, the independent and dependent variables examined, space for the data collection, comparison, and analysis, and for the draw of a conclusion answering to the initial question.
At first, DLO XI is used in which students can modify the variables of vaccination coverage, vaccine efficacy and disease transmissibility (with 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.
The activity above can, also, be performed with DLO VI, in order to save time or not to overload students. In this way they do not need to familiarize themselves with two different simulations. Nevertheless, if both simulations are used, it would be fruitful to mention 1-2 indicative differences between the two simulations (models) despite representing the same natural phenomenon.
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.
In order to make the graph students change the vaccination coverage percentage per 5%, and record the percentage of infected. The infectivity values standing for a mildly and highly infectious disease, must have been defined by the teacher in advance, after tests. It would be useful the teacher to have spent time preparing the lesson to find values that give graphs, indicating clearly the phenomenon of herd immunity.
If students have difficulties in making graphs, some relevant software can be used, providing the teacher thinks it is a more appropriate approach.
Afterwards, students select authentic values of infectivity and vaccination efficacy based on data of real cases of diseases and vaccines, like COVID-19, measles, varicella, and diptheria. Students have to determine the critical percentage of vaccination coverage for the achievement of herd immunity in each case. At some cases the achievement of herd immunity is impossible, and that is a point to be discovered by students.
Then, students are assigned to test themselves the way the infection duration affects herd immunity achievement and the determination of the critical vaccination percentage for the achievement. Student groups are free to opt for the research process applied. After the inquiry, students discuss their findings in the classroom.

6th teaching hour – Herd immunity over time & the role of mass vaccinations of children
Learning objectives

Knowledge	**Skills**	**Attitudes and Behaviours**
Argumentation for the need of ensuring broad vaccination coverage Explanation of the contribution	Testing as a way to answer research questions Modification of variables to carrying out tests	Appreciation of vaccines for their services to public health Appreciation of the worth of vaccination

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of vaccinations to disease eradication Explanation of the contribution of vaccination to the decrease in disease reemergence	Data collection and analysis Data-driven conclusion-making Handling of digital simulations Argumentation about scientific topics	Acknowledgement of the risk of old diseases re-emergence Acknowledgment of the need of the implementation of mass vaccinations in children Awareness about the decrease in vaccinations Consideration of vaccination as a means of human progress Participation in vaccination programs Participation in discussions about the importance of vaccination

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 XIII to answer to these questions. DLO XIII 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.

The activity above follows the process of an 'experimental' inquiry and it would be beneficial for students to use a carefully made worksheet with clearly formulated research questions, variables involved, place for data collection, and place for conclusion making.

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. DLO VII can be used to follow the history of smallpox from its first accounts, through the deadliest pandemics, and finally up to the complete eradication.

The use or SER XIV, which is about the study of the frequency of references of the word 'smallpox' over time, is optional. It could be omitted, or be shown by the teacher with the use of a projector machine, instead of done by students themselves, in order to save time.

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 X 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

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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.
The use of the SER XV about the re-emergence of measles outbreaks can be done by the teacher in a form of demonstration with the use of a projector machine, and students can draw the conclusions from it.

7th teaching hour – Adverse effects of vaccination and the anti-vaccination movement
Learning objectives

Knowledge	Skills	Attitudes and Behaviours
Evaluation of the worries about the adverse effects of vaccines Comparison of % probabilities Description of the process of licensing vaccines Evaluation of the suitability of vaccines	Comparison of probabilities percentages Data-driven conclusion-making Critical thinking and argumentation Handling of digital simulations	Development of a positive attitude towards the safety of vaccines Consideration of vaccination as a means of human progress Decrease of worries about vaccines Development of trust in science Participation in discussions about the safety of vaccination

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 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.
Instead of showing the video, an introductory, non-criticizing discussion could be made with students about the possible reasons they have heard of about not getting vaccinated, the kind and severity of vaccine adverse effects, the necessity of vaccinations, vaccine safety, or other relevant issues.
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, tetanus, varicella, measles, meningococcal disease, polio, 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 XIV 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

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'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.
The use of SER XIV can be done in a form of demonstration with the use of a projector machine.

8th teaching hour – Misinformation about vaccination
Learning objectives

Knowledge	Skills	Attitudes and Behaviours
Description of common attributes of a scientific text Description of common attributes of a scientific misinformation text Evaluation of the trustworthiness of a scientific text by using criteria	Critical reading of texts Critical thinking and argumentation Cooperation and communication Critical appraisal of scientific information	Development of a critical attitude toward scientific information Critical evaluation of scientific information on a daily basis

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 IX 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.
There might be the need for some initial examples be given of linguistic attributes showing trustworthiness from each one of the tree texts. Alternatively, the first text could be examined in detail by the teacher and this analysis could function as a model for the students for the implementation of the trustworthiness criteria to the following texts.
Students form groups of four and are assigned with the critical evaluation of short text extracts concerning vaccination, provided by DLO IX. The texts are about 10 short extracts derived from scientific papers, scientific journalist texts, informative health organisation texts and misinformative texts. Students have to

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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.
If time is limited, each student group could be responsible for the evaluation of a lower number of texts (if possible at least 4 per group) which can be different per student group, or be the same for all students, according to what the teacher thinks more suitable. Groups having the same texts argue successively about their texts during the classroom discussion part.

9th-10th teaching hours – Developing informative material for a pro-vaccination and an anti-misinformation campaign (School project)
Learning objectives (depending on the project option chosen)

Knowledge	Skills	Attitudes and Behaviours
Explanation of the common attributes of science and scientific misinformation texts Evaluation of the trustworthiness of medical texts Detection of medical misinformation Debunking of antivaccination arguments Argumentation in favor of vaccination Explanation of the benefits of vaccination	Critical reading of texts Critical thinking and logical reasoning Communication of scientific ideas to the general public Cooperation and communication Detection and evaluation of information on the Internet Creation of digital presentations and guides	Development of critical attitude towards the scientific information Development of positive towards science communication Participation in discussions about vaccination

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 (SER XVII could be used) 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 or an eight-slide presentation (SER XVII could be used), 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

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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.
The suggested software for the school project from the e-me educational platform can be used to easy incorporate images, videos, links, interactive questions to the user, and the option of non-linear navigation. If some other software is thought to be more appropriate, it could be used as well.
If the teacher thinks is more appropriate, only one project option out of the two could be done by all the students.

11th-14th teaching hours – Presentation of the project outcomes (School project)
Learning objectives

Knowledge	Skills	Attitudes and Behaviours
-	Communication and presentation of scientific topics Active listening and feedback provision Participation in discussions on scientific topics Cooperation and communication Reflection on the learning process	Development of positive attitude towards feedback and opinion exchange Development of a positive image of the personal learning process of each student

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 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 11th and 12th teaching hours.
During the 13th 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 14th 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 improvement of the developed material by the students according to the feedback during the

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presentation is thought as useful since it practices students to the feedback providing and receiving process, and helps them to develop more extensively their competences.
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 (DLO I) 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 behaviors.

Short version of the scenario (10 teaching hours)
The initial (expanded) version of the educational scenario lasts for 14 teaching hours. Difficulties that may arise due to its long duration (e.g. alignment with the Curriculum, availability of rooms, or resources). For that reason a shorter version of the scenario of 10 teaching hours is provided, which can be opted for if the teacher thinks so. The suggested modifications to the structure of the scenario are the following ones:

Expanded version of the scenario (14 hours)	**Short version of the scenario (10 hours)**	**Modifications**
1st-2nd hours	1st hour (fusion)	After the fusion of the 1st and the 2nd hours the activities that are suggested to remain are a very short introduction topic of vaccination, the completion of the KWL table, the projection of the video about the categories of pathogens, the explanation of the basic virus structure, and the study of the virus visualization simulation (with 1-2 viruses per groups instead of 3 viruses),
3rd-5th hours	2nd -4th hours	Remains the same. Some concepts of the 2nd and the 3rd hour of the expanded educational scenario, which are about basic microbiology and immunology concepts, respectively, are also usually included in the school curriculums.
6th-7th hours	5th hour (fusion)	After the fusion of the 6th and the 7th hours the activities that are suggested to remain are the inquiry of achieving herd immunity over time, the study of re-merging measles outbreaks, and the study of probabilities of vaccine adverse effects.
8th-10th hours	6th-8th hours	Remains the same.
11th-14th hours	9th-10th hour (reorganization)	The project presentations phase is reorganized. During the 9th and during a part of the 10th hour the student groups present their project, after some modifications of the time given per group. The part of improvements done after feedback is omitted. The last part of the 10th hour is given for the completion of the KWL table.

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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.

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:

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.

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.

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.

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.

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.

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

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campaign should have.
Academics or university professors with relevant expertise.
Members of the PAFSE consortium with relevant expertise.
II. Educational visits
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:
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.
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 with them about their profession, the future of biomedical research and potential STEM careers in this domain.
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.
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.
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
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

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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
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

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	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
2. Disproves common arguments against vaccination	**Question 2.1:** Mass vaccination programs for children for diseases like the rubella and the measles …

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	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
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

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	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 'a 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

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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
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

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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
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.

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	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

2.2.7. Function of vaccines, vaccination hesitancy and misinformation – Middle School

Main partner responsible
The Educational Approaches to Virtual Reality Lab (EARTH Lab), Department of Primary Education, 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.

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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 an act 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.
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
12 teaching hours (extended version of the scenario) organized in continuous two-hour periods if possible.
8 teaching hours (short version of the scenario).
Designed for Biology or Health Sciences classes of high school (senior high school) grades (K7-9 grades).
The scenario might also be applicable for a unified Science syllabus.
The Biology (or Health Sciences, or Science) teacher could cooperate with the English language teacher in order to combine Science Learning with English Language Instruction, according to the Content and Language integrated learning (CLIL). In this way both scientific literacy and English fluency are promoted.
The learning sequence is appropriate for this method since all the DLOs and SERs are available in English

Content
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 and interpretation 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 (science communication).
STEM education for the confrontation of a crucial contemporary phenomenon with devastating consequences to public health (vaccine hesitancy).

Content glossary
Adaptive or specific 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 the Alzheimer's disease.
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 or nonspecific 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.

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Primary immune response: The immune response is characterized as primary when the immune system encounters a pathogen for the first time.
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.
Recombinant 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.
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

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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. In structured inquiry students are given the research question to-be-answered, as well as detailed step-by-step guidance of the entire process of inquiry. In guided inquiry student are only given the research question to-be-answered and the decision-making processes about the research procedure are set up to them'
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.
'Problem solving: The problem solving approach includes students groups practicing higher thinking skills and making decisions in to analyze a given problem and propose solutions to it. At first, the problem settings are described to students along with the desirable aim, and some basic limitations. Each groups analyzes the problem and comes up with as more and as diverse solutions possible (creative thinking), and then evaluates these ideas (critical thinking) through group discussions, pros and cons comparisons, assessment according to criteria, pilot tests, tests, or other ways, and come down to a final proposed solution, as detailed as possible. After testing the proposed solution, or getting feedback on it, the group might have to repeat the steps of improve the solution'.
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
Knowledge (Core Concepts)
a) Transdisciplinary concepts: Critical health literacy, public health literacy, pseudoscience and misinformation, scientific numeracy, science communication and journalism.
b) Specific content concepts: Communicable diseases, pathogens, viruses, bacteria, toxins, virus life cycles, immune system, immune response (primary and secondary), adaptive immunity, antibodies,

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memory cells, vaccines, vaccination, live-attenuated vaccines, inactivated vaccines, recombinant 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.

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.

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 12th 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.
Intermediate, or at least limited, fluency in English in case that DLOs and SERs other than the ones of the PAFSE repository are used.

School research project
Topics
How do vaccines protect me from infectious diseases?

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How does vaccination protect public health?
How can I identify a text of medical misinformation?
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.
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.).

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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 methods

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.
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

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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 instruction 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.
Inquiry-based-learning contextualization of the scenario's digital learning objects (structured inquiry, guided inquiry, case study, argumentation, problem solving).
The use of graphic organizers, such as the KWL tables and concept maps, in instruction.
Teaching of critical reading and recognizing 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.
Ways to handle controversial socioscientific issues in the classroom.

Digital Learning Objects (DLOs)
DLOs created specifically for the needs of the PAFSE project
'Table of the learning procedure about vaccines'
http://photodentro.pafse.eu/handle/8586/50
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.
'Mechanisms of specific immune response'
http://photodentro.pafse.eu/handle/8586/242
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.
'Concept map about the immune response'
http://photodentro.pafse.eu/handle/8586/148
Semi-structured concept map concerning the main points of immune response.
'Function of vaccine types'
http://photodentro.pafse.eu/handle/8586/172
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.
'Concept map about vaccines'
http://photodentro.pafse.eu/handle/8586/157
Semi-structured concept map concerning the main points of vaccine function and types.
'Parameters affecting herd immunity'
http://photodentro.pafse.eu/handle/8586/171
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

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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.
'Timeline of smallpox'
http://photodentro.pafse.eu/handle/8586/243
Timeline of the evolution and eradication of smallpox, including ancient references to the disease, historical epidemics and pandemics, the development of the first vaccines against it, the implementation of mass vaccination programmes, and the total eradication of the disease.
'Vaccine efficacies and adverse effects'
http://photodentro.pafse.eu/handle/8586/160
Visualization of vaccine efficacies and the frequencies 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.
'Information and misinformation about vaccination'
http://photodentro.pafse.eu/handle/8586/241
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.
DLOs which have been retrieved from online resources
'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.
'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.
'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.
Supplementary Educational Resources (SERs)
SERs created specifically for the needs of the PAFSE project
'Conceptions about microbes, immunity, and vaccines'
http://photodentro.pafse.eu/handle/8586/173
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.
SERs which have been retrieved from online resources
'The importance of vaccination'
https://www.cdc.gov/globalhealth/socialmedia/cards/images/2-3million_fb_ig.jpg
Infographic by the Center for Disease Control and Prevention highlighting the importance of vaccination by using numerical data.
'Polio eradication'
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.
'Vaccination against the pneumoniococcus'
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.
'Microorganism scale'
https://learn.genetics.utah.edu/content/cells/scale/
Dynamic visualization by the educational repository Learn Genetics, which depicts the relevant size of

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several cells and biological structures with emphasis on microorganisms (bacteria, viruses, protozoa, yeast cells).
'Macrophage phagocytosis'
https://www.youtube.com/watch?v=BlPlgGbb2IU
YouTube video showing the phagocytosis of bacteria by a macrophage as captured with an optical microscope.
'How vaccines work'
https://www.youtube.com/watch?v=-muIoWofsCE
Educational YouTube video by the channel Oxford VaccineGroup regarding the way vaccines work.
'Vaccines against COVID-19'
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.
'What herd immunity is'
https://www.youtube.com/watch?v=XJFoOCmJsdg
Educational YouTube visualization video presenting the mechanism behind herd immunity.
'Measles outbreaks and vaccine coverage'
https://fred.publichealth.pitt.edu/measles
Simulation showing the emergence of measles outbreaks in USA cities in the case where vaccination coverage would fail.
'Misinformation about vaccine adverse effects'
https://www.youtube.com/watch?v=zBkVCpbNnkU
Educational YouTube video by the channel Kurzgesagt about the degree of danger vaccine adverse effects have.
'E-me platform H5P tools for the school project'
H5P tools of the e-me platform (https://e-me4all.eu/). By choosing 'e-me content' students can use the 'Course Presentation' tool to create an interactive and multimodal presentation promoting vaccination, including texts, images, videos, short questions, etc, for the health promotion campaign, and the 'Interactive Book' to write an interactive and multimodal guide against vaccination, having the same technical potential, as well.

Teacher-learning activities

Some educational activities have been framed in dotted frames, like the following one:
These activities could be seen as optional under conditions. Even though they are parts of the educational scenario, they are not inseparable ones, and they could be omitted if the teacher thinks so, mainly due to reasons relevant to restricted teaching time, limited student competences, or low student motives. This can be done according teacher's will and the omission of some framed activities does not affect the other ones, e. g. the framed activities of the 2nd, 5th, and 6th hours can be omitted, thus the framed activities of the 1st, 3rd, and 4th hours be carried hours properly. Some of the framed activities might be used as optional activities for more 'advances' student groups that end their task earlier than the rest, or as alternative, or optional homework for students interested.

1st teaching hour – Is it important to learn about vaccination?

Learning objectives

Knowledge	Skills	Attitudes and Behaviours
-	Recall of previous knowledge	Interest about vaccination-related topics Expression of expectation from the learning sequence

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 15 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:
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.
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.
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.
The interactive map (DLO X) 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.
The suggested educational resources above are indicative. There is no need to use all of them. The teacher selects which resources are thought to be more appropriate to enhance the teaching process, and utilizes them. Educational resources other than these might also be used if the teacher would like so. It is estimated that 2-3 educational resources might be enough. They can be shown with a projector machine, or some of them could be distributed in print.
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.
In order to have students use DLO I, the teach must previously have been signed in to the platform https://mathspace.gr/pafse/index.php?signIn=1l, and then enter all students one-to-one so that personal passwords are issued for each of them. These passwords are needed for each students to enter the DLO I and submit their answers. Otherwise, a printed version of the KWL table could be distributed.

2nd teaching hour – Variety, structure and life cycle of microorganisms

Learning objectives

Knowledge	Skills	Attitudes and Behaviours
Description of the mechanism bacteria cause damage to humans Description of the mechanism viruses cause damage to humans Description of the basic viruses	Recognition of visual representations bacteria and viruses Handling of digital simulations	-

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structure Vague description of viruses reproduction Comparison and contrast of bacteria and viruses		

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.
Then, a short reference on bacteria takes place. The teacher briefly explains the main features of bacterial structure and morphology. Some videos, images, or photographs showing bacteria can be used. The aim is to give student a brief idea on the cellular structure of bacteria, their shape, the existence of bacterial cell and DNA, and their way of reproduction.
Students, now, focus on virus biology with the aid of DLO XI. 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 IX and compare them to one another concerning their morphology and anatomy, their hosts, and their genetic material.
Students do not have to use the explanatory texts of DLO XI in detail, which might be too hard for their level of conceptual understanding, nor do they have to focus on the details of the diagrammatic representations of virus life cycles. It is suggested to scaffold students with a worksheet that guides them to answer shortly some very specific questions concerning the virus name, the disease name, the host, the virus structure (protein capsid and lipid envelope), the virus dimensions, and the type of genetic material. No detailed knowledge on life cycles or high fluency in English are needed to detect these pieces of information.

3rd teaching hour – The elements of the adaptive immune response
Learning objectives

Knowledge	Skills	Attitudes and Behaviours
Distinction of adaptive (specific) and innate (nonspecific) immunity Explanation of the roles of memory cells and antibodies Definition of primary and secondary immune response Comparison and contrast of primary and secondary immune response	Handling of digital simulations Graph interpretation Concept mapping	-

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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 or specific immunity and the differences between primary and secondary immune response.

The immunity concepts and processes included in the simulation are much more than the basic concepts and processes that the ones included in the learning objectives. This is done in the service of a fuller and more concrete conceptual understanding, especially for students showing a more intense interest in the topic. The main points that the lesson, and the learning objectives, focus on are the differences between innate (nonspecific) and adaptive (specific) immunity, the differences of primary and secondary immune response regarding the rate or the response and the quantity of antibodies produced, the fact that the secondary immune response lays at the work of memory cells, and the nature and role of antibodies, meaning they are acellular substances of limited life span, and at no case the same with the entire immune system.

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 VI 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.

It is suggested not to focus on the names of the immune cell types during the instruction, but to put emphasis on their roles, instead. Specific mentions must be made on the function of the memory cells and the antibodies. In other word, what middle school students should memorize is the roles of memory cells and antibodies, and the differences between primary and secondary immune response.

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.

A graph showing primary and secondary immune responses is a visual way of representing their function and differences, and may be helpful for some students to better understanding their differences regarding the response rate and quantity of antibodies, therefore.

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.

The concept map is complex and includes several empty frames (concepts), needing therefore sufficient

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time for its completion. If time is not enough, it can be an activity only for student groups having finished their work earlier than the others. Otherwise, some the answers for some empty frames may be given to students as hints, as a means to make the completion of the concept map easier, depending on the points the teacher thinks to be more difficult, or has highlighted, or not highlighted, during the instruction,

4th teaching hour – Types and function of vaccines

Learning objectives

Knowledge	Skills	Attitudes and Behaviours
Explanation of the way vaccines work Argumentation for the use of vaccines as a means of disease prevention Naming of different vaccine types Description of different vaccine types Comparison and contrast of different vaccine types.	Discussion on scientific topics Argumentation and decision-making Cooperation and communication Handling of digital simulations Concept mapping	Appreciation of vaccines for their services to personal health Appreciation of vaccines for their services to disease prevention Acknowledgement of the interaction between science and technology

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 VII 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:

Live-attenuated pathogen vaccines.
Inactivated pathogen vaccines.
Recombined microorganism vaccines / viral vector vaccines.
DNA vaccines.
RNA vaccines.
Protein subunit vaccines.
Virus-like protein (VLP) vaccines
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, some of which may be utilized during the lesson, are the following ones:

A highly infectious bacterium which produces harmful protein toxins.

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A bacterium causing a very severe disease, and for that reason the development of the strongest immune response possible is preferable.
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).
A highly infectious and dangerous bacterium with characteristic protein structures on its surface.
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.
A very dangerous DNA virus with well-studied structure and genome.
A very dangerous RNA virus with well-studied structure and genome.
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.
A novel very dangerous virus which can be easily handled in the laboratory.
A virus which mutates at a very high rate.
A very contagious and dangerous virus, which is a variant of an already existing virus with very low infectivity.
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).
The pathogen cases above are indicative. Each student group could work on 4-6 cases, different for each group, for time-saving reasons. During the classroom discussion following, students having worked on the same cases argue on their choices.
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.
The video about the COVID-19 vaccines is optional, but is suggested on the grounds of students' interest on the topics, since COVID-19 vaccines had dominated the public discourse about science during the COVID-19 pandemic (e.g. mRNA vaccines). Alternatively, the time could be used for the completion of the concept map, instead of the video.
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.
The concept map is complex and includes several empty frames (concepts), needing therefore sufficient time for its completion. If time is not enough, it can be an activity only for student groups having finished their work earlier than the others. Otherwise some the answers for some empty frames may be given to students as hints, as a means to make the completion of the concept map easier, depending on the points the teacher thinks to be more difficult, or has highlighted, or not highlighted, during the instruction,

5th teaching hour – How different parameters affect the achievement of herd immunity
Learning objectives

Knowledge	Skills	Attitudes and Behaviours
Explanation of how herd immunity works Argumentation for the vaccination-serviced protection of unvaccinated people Explanation of how disease transmissibility, vaccine efficacy, and vaccine coverage affect herd immunity Argumentation for the need of ensuring broad vaccine	Modification of variables to carrying out tests Data collection and analysis Data-driven conclusion-making Graph interpretation Argumentation and discussion concerning scientific topics Handling of digital simulations	Appreciation of vaccines for their services to public health Acknowledgement of the effect of personal decision-making to the society Acknowledgement of the effect of the collective behavior to each person Consideration of vaccination as a solidarity action Awareness about the value of

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coverage of a population		vaccination Adoption of experimentation as a way of examining the natural world

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 teacher is suggested to address some questions to the classroom as an engagement activity. These questions could be whether it is meaningful for one to get vaccinated supposed 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 addresses 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 IX.

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 duration of the disease. Other variables which might have been expressed (e.g., citizens' social behavior, application of hygiene rules, the existence of already-immune population from past infections, spatial or geographical distribution of vaccination coverage etc.) although being completely important as well, are not going to be tested during this inquiry process.

The distinction between dependent and independent variables during an experiment or test, seems to be useful for this activity. It is also important to clarify that a experiment or test to study a research question, it is important to try to ensure that only one independent variable is modified per test, the one the effect of which on the dependent variables one wants to examine. The other independent variables should remain as stable as possible, in order to get comparable results.

The activities of this hour include the 'experimental' test of one research question per time. It would be useful to have worksheets guiding students to their 'experimental' work. For each inquiry process, there should in include a clearly formulated question, the independent and dependent variables examined, space for the data collection, comparison, and analysis, and for the draw of a conclusion answering to the initial question.

At first, DLO VI is used in which students can modify the variables of vaccination coverage, vaccine efficacy and disease infectivity. They are given two infectivity 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 the DLO VI for further testing. 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.

In order to make the graph students change the vaccination coverage percentage per 5%, and record the percentage of infected. The infectivity values standing for a mildly and highly infectious disease, must have been defined by the teacher in advance, after tests. It would be useful the teacher to have spent time

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preparing the lesson to find values that give graphs, indicating clearly the phenomenon of herd immunity. If students have difficulties in making graphs, some appropriate software can be used, providing the teacher thinks it is a more appropriate approach.
Afterwards, students select authentic values of infectivity and vaccination efficacy based on data of real cases of diseases and vaccines, like COVID-19, measles, varicella, and diptheria. Students have to determine the critical percentage of vaccination coverage for the achievement of herd immunity in each case. At some cases the achievement of herd immunity is impossible, and that is a point to be discovered by students.
Then, students are assigned to test themselves the way the infection duration affects herd immunity achievement and the determination of the critical vaccination percentage for the achievement. Student groups are free to opt for the research process applied. After the inquiry, students discuss their findings in the classroom.

6th teaching hour – Herd immunity over time & the role of mass vaccinations of children
Learning objectives

Knowledge	**Skills**	**Attitudes and Behaviours**
Argumentation for the need of ensuring broad vaccination coverage Explanation of the contribution of vaccinations to disease eradication Explanation of the contribution of vaccination to the decrease in disease reemergence	Testing as a way to answer research questions Modification of variables to carrying out tests Data collection and analysis Data-driven conclusion-making Handling of digital simulations Argumentation about scientific topics	Appreciation of vaccines for their services to public health Acknowledgement of the risk of old diseases re-emergence Acknowledgment of the need of the implementation of mass vaccinations in children Awareness about the decrease in vaccinations Consideration of vaccination as a means of human progress Participation in vaccination programs

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 the inquiry process. 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.
The activity above follows the process of an 'experimental' inquiry and it would be beneficial for students to use a carefully made worksheet with clearly formulated research questions, variables involved, place for data collection, and place for conclusion making.
Afterwards, students discuss in the classroom their conclusions and estimate how realistic the total elimination of communicable diseases would be. They focus on the case of smallpox with the aid of DLO VII. 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. However, the intensification of a worldwide mass vaccination program from 1967 by the World Health

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Organization lead to record of the last natural case of smallpox in 1977 and the disease was officially declared as eradicated in 1980. 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. DLO VII can be used to follow the history of smallpox from its first accounts, through the deadliest pandemics, and finally up to the complete eradication.
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 X 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 X 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.
The use of the SER X about the re-emergence of measles outbreaks can be done by the teacher in a form of demonstration with the use of a projector machine, and students can draw the conclusions from it.

7th teaching hour – Adverse effects of vaccination and the anti-vaccination movement
Learning objectives

Knowledge	Skills	Attitudes and Behaviours
Evaluation of the worries about the adverse effects of vaccines Comparison of % probabilities Evaluation of the suitability of vaccines	Comparison of probabilities percentages Data-driven conclusion-making Critical thinking and argumentation Handling of digital simulations	Development of a positive attitude towards the safety of vaccines Consideration of vaccination as a means of human progress Decrease of worries about vaccines Development of trust in science Participation in discussions about the safety of vaccination

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 XI 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 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.
Instead of showing the video, an introductory, non-criticizing discussion could be made with students about the possible reasons they have heard of about not getting vaccinated, the kind and severity of vaccine adverse effects, the necessity of vaccinations, vaccine safety, or other relevant issues.
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, tetanus,

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varicella, measles, meningococcal disease, polio, 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.
Then, students are asked whether they think antivaccination movements are a recent phenomenon. 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. Then, they 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.

8th teaching hour – Misinformation about vaccination

Learning objectives

Knowledge	Skills	Attitudes and Behaviours
Description of common attributes of a scientific text Description of common attributes of a scientific misinformation text Evaluation of the trustworthiness of a scientific text by using criteria	Critical reading of texts Critical thinking and argumentation Cooperation and communication Critical appraisal of scientific information	Development of a critical attitude toward scientific information Critical evaluation of scientific information on a daily basis

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 IX 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.
There might be the need for some initial examples be given of linguistic attributes showing trustworthiness from each one of the tree texts. Alternatively, the first text could be examined in detail by the teacher and this analysis could function as a model for the students for the implementation of the trustworthiness criteria to the following texts.
Students form groups of four and are assigned with the critical evaluation of short text extracts concerning

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vaccination, provided by DLO IX. The texts are about 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.
If time is limited, each student group could be responsible for the evaluation of a lower number of texts (if possible at least 4 per group) which can be different per student group, or be the same for all students, according to what the teacher thinks more suitable. Groups having the same texts argue successively about their texts during the classroom discussion part.

9th-10th teaching hours – Developing informative material for a pro-vaccination and an anti-misinformation campaign (School project)
Learning objectives (depending on the project option chosen)

Knowledge	**Skills**	**Attitudes and Behaviours**
Explanation of the common attributes of science and scientific misinformation texts Evaluation of the trustworthiness of medical texts Detection of medical misinformation Debunking of antivaccination arguments Argumentation in favor of vaccination Explanation of the benefits of vaccination	Critical reading of texts Critical thinking and logical reasoning Communication of scientific ideas to the general public Cooperation and communication Detection and evaluation of information on the Internet Creation of digital presentations and guides	Development of critical attitude towards the scientific information Development of positive towards science communication Participation in discussions about vaccination

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 (SER XII could be used) 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 or an eight-slide presentation (SER XII could be used), 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

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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.
The suggested software for the school project from the e-me educational platform can be used to easy incorporate images, videos, links, interactive questions to the user, and the option of non-linear navigation. If some other software is thought to be more appropriate, it could be used as well.
If the teacher thinks is more appropriate, only one project option out of the two could be done by all the students.

11th-12th teaching hours – Presentation of the project outcomes (School project)
Learning objectives

Knowledge	Skills	Attitudes and Behaviours
-	Communication and presentation of scientific topics Participation in discussions on scientific topics Cooperation and communication Reflection on the learning process	Development of positive attitude towards opinion exchange Development of a positive image of the personal learning process of each student

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 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 11th and, partly, the 12th teaching hour.
The rest of 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 (DLO I) 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 behaviors.

Short version of the scenario (8 teaching hours)
The initial (expanded) version of the educational scenario lasts for 14 teaching hours. Difficulties that may arise due to its long duration (e.g. alignment with the Curriculum, availability of rooms, or resources). For that reason a shorter version of the scenario of 10 teaching hours is provided, which can be opted for if the teacher thinks so. The suggested modifications to the structure of the scenario are the following ones:

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Expanded version of the scenario (12 hours)	Short version of the scenario (8 hours)	Modifications
1st-2nd hours	1st hour (fusion)	After the fusion of the 1st and the 2nd hours the activities that are suggested to remain are a short introduction topic of vaccination through examples, the explanation of the basic bacterial and viral structure, and the study of the virus visualization simulation (with 1-2 viruses per groups instead of 3 viruses),
3rd-5th hours	2nd -4th hours	Remain the same. Some concepts of the 2nd and the 3rd hour of the expanded educational scenario, which are about basic microbiology and immunology concepts, respectively, are usually included in the school curriculums, as well.
6th-7th hours	5th hour (fusion)	After the fusion of the 6th and the 7th hours the activities that are suggested to remain are the inquiry of achieving herd immunity over time, the study of re-merging measles outbreaks, and the study of probabilities of vaccine adverse effects.
8th hour	6th hour (optional)	Remains the same. However, it highlights a non-biological topic (scientific misinformation) and the teacher could omit it, if they want to insist only on the biological phenomena.
9th-10th hours	7th hour (fusion)	The projects focus on very specific topics, so that they can be completed within 1 hour. Such topics could be the presentation of a virus structure and life cycle, 1-2 vaccine types, debunking of 1-2 antivaccination arguments, the explanation of herd immunity, the conduct of a micro-experiment with one simulation, etc.
11th-12th hours	8th hour (fusion)	Students do shortly present their work to one another

Basic principles of microbiology, immunology, and vaccination are usually parts of the middle school curriculum. If the instruction of these topics has been done earlier than the enactment of the scenario, the first 3 hours of the expanded version might be omitted.

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

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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 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:
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.
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.
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.
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.
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.
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.
Academics or university professors with relevant expertise.
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

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summarize the context of the visit and link it to the learning sequence in school.
Some suggested places for educational visits are listed below:
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.
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 with them about their profession, the future of biomedical research and potential STEM careers in this domain.
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.
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.
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
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

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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
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

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	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
2. Disproves common arguments against vaccination	**Question 2.1:** Mass vaccination programs for children for diseases like the rubella and the measles …

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	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 'a 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.

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	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
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

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	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
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

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	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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2.3. Portuguese Road Safety Association (PRP)

AMENDMENTS

Amendments of the revised version of the educational scenario entitled: *"Sustainable Mobility"*

The changes made on the educational scenario "Sustainable Mobility" lay on mild adjustments according to the feedback from internal and external experts who participated in designing and developing educational scenarios and also of the teachers who participated in the workshops and in the implementation of the scenario.

The number of sessions was increased from 5 to 6 with the inclusion of session 3, "Ecological footprint" which origin a new digital educational resource, "Ecological footprint commitment".

Another new digital educational resource was added, a "step by step" of how to implement a questionnaire to be used on lesson 7.

It was added to the scenario the address where the DLO's and DER's are temporarily hosted, which will later be made available in Photodentro Pafse after the adjustments and improvements to the resources are completed.

Amendments of the revised version of the educational scenario entitled: *"Road traffic crashes – a public health issue"*

The main changes in the educational scenario followed teachers' suggestions after the first workshop for teachers and scenario's implementation and also from internal and external experts who participated in designing and developing educational scenarios. The order the contents was changes in some of the lessons, the learning objectives of each lesson were added, and guided questions for the activities were provided as complementary educational resources.

Besides the teachers' suggestions, new learning objects were added: a presentation highlighting the SDGs related to road safety (DER_10), the link for a dashboard with road crash statistics in Portugal (DER_11), an image with the road safety system and contributing factors for road crashes (DER_12), crash test videos (DER_13), a presentation with the steps of the scientific method (DER_14) and two quizzes: steps of the scientific method (DLO_5) and risky behaviours in traffic (DLO_6).

It was added to the scenario the address where the DLO's and DER's are temporarily hosted, which will later be made available in Photodentro Pafse after the adjustments and improvements to the resources are completed.

Amendments of the revised version of the educational scenario entitled: *"Road traffic crash risk factors"*

Minor adjustments and improvements were made to the scenario as well as to the DLO'S and DER's to improve the learning experience, facilitate the implementation of the scenario and making it more versatile, following the recommendations and suggestions of internal and external experts who participated in designing and developing educational scenarios, including the teachers involved in workshops and implementation of scenarios.

Regarding the scenario, information was added to the context of the scenario, some of the activities proposed in the first version were eliminated in order to reduce the implementation time of the scenario and consequently the order of some activities was reorganized.

It was added to the scenario the address where the DLO's and DER's are temporarily hosted, which will later be made available in Photodentro Pafse after the adjustments and improvements to the resources

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are completed.
Some adjustments and improvements were made to some educational resources in terms of design, format and interactivity.

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2.3.1. Sustainable mobility and road safety

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

6 sessions of 40-45 minutes (lesson 1 – lesson 6)
6 sessions of 40-45 minutes for supplementary learning activities and school project (lesson 7 – lesson 12)

Classroom organization requirements

From session 1 to session 6, 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.

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<u>Content glossary</u>

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.

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

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generated. 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.

Equity. Being fair and impartial, ensuring that everyone has access to the resources, opportunities, power

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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.

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.

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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 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

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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.
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

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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.
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

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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.

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,

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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.

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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.

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.

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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.
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.

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✓ 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

- 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

DLO's and DER's are temporarily hosted on the website: https://prp.pt/pafse/ - password to access: pafse2022.

All resources will be made available on the Photodentro platform of the PAFSE project https://pafse.eu/pt/photodentro-pafse-pt/ as soon as the final adjustments are made, which is expected to happen in September 2023.

- New
  - **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).

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

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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.
  - **New Digital Educational Resource 20**: Ecological footprint commitment layout
  - **New Digital Educational Resource 21**: Step by step on applying a questionnaire

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

- 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)

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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* each 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**

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

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environmental pollution has a direct impact on the health and quality of life of the populations.

Lesson 2: Environmental protection and social and economic dimension

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 – Digital Educational Resource 10: Noise Level Scale**

(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: Air pollution: how it affects our health**

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: Noise pollution — European Environment Agency (europa.eu)**

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:**

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.

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- **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**

Lesson 3: Ecological footprint

- ✓ **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 fewer animal products, adopting more environmentally friendly travel habits, saving on water consumption...) - **New Digital Educational Resource 20**: Ecological footprint commitment layout

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<u>Lesson 4: EcoMobility</u>

Sustainable Development and SDGs.

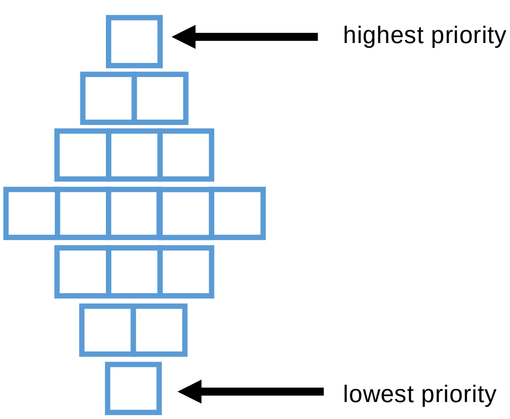
Students are asked if they know what is Sustainable Development and how many are the Sustainable Development Goals defined in the Global Agenda launched by the United Nations.

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.



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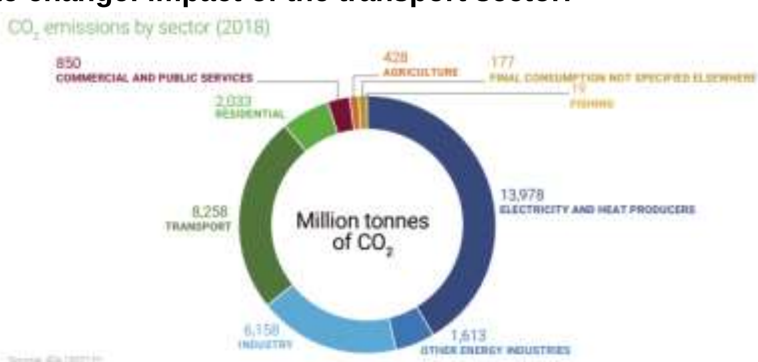
➢ **Debate/Conclusion: Was it easy to decide which goals were the most important? If not, why?**
Many of these issues are interconnected, which means we can't address them on their own. For example, if we don't address poverty and provide everyone on the planet with a sustainable way to produce food, 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:**



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

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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.

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.

Lesson 5: 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.

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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.

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 **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 6 - 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**.

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.

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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.

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 4.**

Lesson 7-forward:

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.**

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 3 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.

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- 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.

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 ...)

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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.

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).

<u>Data Analysis and Reporting</u>

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.

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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.

Assessment Questionnaire- Knowledge, Skills, Beliefs, attitudes and behavior
Scenario topic: Sustainable Mobility

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.

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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.
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	

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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; 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.

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	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.

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	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.
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.

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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

2.3.2. 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

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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, 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)

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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.

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.

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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 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.

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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.
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.

<u>Pedagogical glossary</u>

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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. 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.
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

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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.

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

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.

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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).
- 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.

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✓ 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</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.

<u>Digital Learning Objects (DLO) & Digital Educational Resources (DER)</u>

DLO's and DER's are temporarily hosted on the website: https://prp.pt/pafse/ - password to access: pafse2022.

All resources will be made available on the Photodentro platform of the PAFSE project https://pafse.eu/pt/photodentro-pafse-pt/ as soon as the final adjustments are made, which is expected to happen in September 2023.

<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).
- **DER_10 –**Sustainable Development Goal (SDG) – presentation highlighting the goals related to road safety (SDGs 3 and 11, targets 3.6, 11.2, 3.D).
- **DER_14 –** steps of scientific method – presentation;
- **DLO_1 –** road crash simulators: stop distance, crash force, visual field, run-over.

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- **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:

  - 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.
- **DLO_5 –** steps of scientific method – quiz;
- **DLO_6 –** risky behaviours in traffic – quiz;

From other sources/high-quality selected platforms

- **DER_3 –** Top ten causes of death worldwide (WHO): https://ourworldindata.org/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
- **DLO_4 –** Roads kill (Pulitzer center): https://roadskillmap.com
- **DER_7 –** Road safety statistics (European Commission):

  https://ec.europa.eu/transport/road_safety/specialist/statistics/map-viewer/
- **DER_8 –** Road deaths in the European Union – latest data (ETSC): https://etsc.eu/euroadsafetydata/
- **DER_9 –** Walking and Cycling Data (ETSC): https://etsc.eu/walking-and-cycling-data/
- **DER_11 –** Dashboard – road crash statistics in Portugal (PRP)
- **DER_12 –** Elements of road safety system and contributing factors for road crashes – image
- **DER_13 –** Crash tests videos: helmet motorcyclists, pedestrian run-over, seat belt 1, seat belt 2

Complementary

- Road safety indicators based on roadside observations – Baseline project: https://www.baseline.vias.be
- Guided questions for activities of lessons 1, 2 and 3.

Teaching -learning activities

Principal target

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- 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.

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://ourworldindata.org/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? Guided questions for the activity are provided to the students.

At the end of the class, students should be able to: define Public Health; identify Road Safety as a Public Health problem; identify road crashes as one of the main causes of death in the world and in the country; research, analyze and interpret statistical data to support their conclusions.

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 (**DER_10**). 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-

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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?”. Guided questions for the activity are provided to the students.

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/
- **DLO_4 -** Roads kill (Pulitzer center): https://roadskillmap.com
- **DER_7 -** Road traffic mortality (WHO): https://www.who.int/data/gho/data/themes/topics/topic-details/GHO/road-traffic-mortality
- **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/
- **DER_11 –** Dashboard – road crash statistics in Portugal (PRP)

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.

At the end of the lesson, students should be able to: recognize road accidents as one of the main causes of death and disability; define Sustainable Development Goal 3.6; define and calculate health indicators in the context of road safety; research, analyze and interpret statistical data to characterize road accidents.

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 (**DER_12 –** Elements of road safety system and contributing factors for road crashes). 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:** stop distance, crash force, visual field, run-over) and to watch the crash test videos (**DER_13:** Crash tests videos: helmet motorcyclists, pedestrian run-over, seat belt 1, seat belt 2). 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. Guided questions for the activity are provided to the students. One of the students of each group presents the results to the class. The results are discussed in the class.

At the end of the lesson, students should be able to: identify risk behaviors as the main causes of road crashes; identify risky behaviours in traffic and its relationship with the risk of crash and the severity of their consequences.

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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 (**DLO_6**).

<u>Lesson 4/5</u> – 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 – includes a presentation with the steps of the scientific method – **DER_14** – and a quiz – **DLO_5**) 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:

- *<u>First task</u>*: 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.
- *<u>Second task</u>*: 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.
- *<u>Third task</u>*: build an app (online form with Microsoft forms, Google forms, or other) for data collection of observed behaviours for the same road safety indicator.

At the end of the classes, students should be able to: identify the steps of the scientific method; define, plan and execute a roadside observation survey; build data collection tools and databases; use a spreadsheet to calculate road safety indicators (counts, percentages) and graphs with the results.
Evaluation: tasks produced by the groups.

<u>Lesson 6 - forward</u>
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.

<u>Supplementary learning resources and educational activities</u>

During lesson 6 or in the sessions devoted to the development of the research project is desirable to organize:

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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 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.

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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)

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

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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 crashes 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, …).

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	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. 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	

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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. **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.

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	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.** 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. **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.

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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

2.3.3. 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. 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 mainly 9th grade 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 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

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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)

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

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

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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.

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

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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, 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.

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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.
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.

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Instantaneous speed: is the limit of the average speed as the duration of the time interval approaches zero. Speed is not the same as velocity.
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.
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.
Group Work: Deepens knowledge, develops research and problem-solving skills; develops attitudes of

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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.

Indicative literature

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Road Safety at Work Definitions & Glossary | Road Safety at Work
Queensland government (2020), Department of Transport and Main Roads "Data Analysis Road Crash Glossary" https://www.webcrash.transport.qld.gov.au/webcrash2/external/daupage/docs/glossary.pdf
Cambridge dictionary https://dictionary.cambridge.org/pt/dicionario/ingles/fact-checking
California State University, Meriam Library https://libguides.csuchico.edu/c.php?g=414315&p=2822716
Walsh, J. Michael; Gier, Johan J.; Christopherson, Asborg S.; Verstraete, Alain G. (11 August 2010). "Drugs and Driving". Traffic Injury Prevention. 5 (3): 241–253. doi:10.1080/15389580490465292. PMID 15276925. S2CID 23160488.
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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
-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.

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- 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.

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.

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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:
  - Quantitative – questionnaire in paper.
  - Qualitative - students project.

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✓ 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
The Haddon Matrix (risk factors of road traffic injuries).

1. 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)
DLO's and DER's are temporarily hosted on the website: https://prp.pt/pafse/ - password to access: pafse2022.
All resources will be made available on the Photodentro platform of the PAFSE project https://pafse.eu/pt/photodentro-pafse-pt/ as soon as the final adjustments are made, which is expected to happen in September 2023.

New DLO's (*developed by the project team*):

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1. New DLO Stop distance (simulator)
2. New DLO – Field of view, speed impact (simulator)
3. New DLO – Run-over (Simulator)
4. New DLO – Speed (Quiz: True/False)
5. New DLO Crash Forces calculator (simulator)
6. New DLO –Safety equipment - Myths and Beliefs (Quiz: True/False)
7. New DLO - Distraction (Drag & Drop)
8. New DLO - BAC (simulator)
9. New DLO – Risk of accident and effects of alcohol on the human body (infographic)
10. New DLO - Alcohol - Myths and Beliefs (Quiz: True/False)
11. New DLO - Step-by-step questionnaire on road accident risk factors (power BI)

Digital Educational Resources (DER)

1. New DER - Road crashes, the health and societal burden (powerpoint)
2. New DER – CAART – checking technique (infographic)
3. New DER - Road system elements (infographic)
4. New DER Haddon Matrix (infographic)
5. New DER - Task performance in traffic (infographic)
6. New DER – Field of view (infographic)
7. New DER – How many collisions do you think that happen in a crash accident? (infographic)
8. New DER - collision interval time and pressure (infographic)
9. New DER – Attention game (image - calculation sequence + text - with a story + grid – accounting of errors and questions)
10. New DER –Types of Distraction (infographic)
11. New DER – Fatigue (infographic)
12. New DER – Alcohol absorption and elimination (infographic)

<u>From other sources (only a few of these will be selected for the final scenario):</u>

13. DER – Old and new car crash test (video) https://www.youtube.com/watch?v=C_r5UJrxcck
14. DER – Crash test without seatbelt and with seatbelt (video) https://youtu.be/hNw1-OPwiKs
15. DER – Airbag Crash test (video) How do airbags work? - YouTube

<u>Complementary</u>

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

The Global status report on road safety 2018*, launched by WHO in December 2018*

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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

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Science classes
9th grade (+/- 15 years old students)
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.

Lesson 1 - Road crashes a public health problem

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 1 - Road crashes, the health and societal burden (powerpoint)** 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 2 – 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

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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 **New DER 3 - Road system elements (Infographic).**

To conclude, the teacher will show the **New DER 4 - Haddon Matrix (Infographic),** with examples of safety measures, before, during and after the accident, reinforcing that to reduce the risks and consequences of an accident, theoretically, we have to improve the performance of the 3 elements of the road system.

MATRIZ DE HADDON	Utentes	Veículo e Equipamento	Ambiente Rodoviário
Antes do Acidente	• Formação de Condutores; • Educação Rodoviária; • Campanhas de Segurança Rodoviária;	• Sistema ABS - Travões; • Sistema Eletrónico de Estabilidade - ESC; • Travagem Autónoma de Emergência - AEB;	• Pavimento anti-derrapante; • Iluminação; • Sinalização;
Durante o Acidente	• Capacete; • Sistema de Retenção de Crianças; • Cotoveleiras e Joelheiras;	• Pré-tensores dos cintos de segurança; • Airbags; • Zonas de deformação;	• Barreiras de Proteção; • Sistemas de Proteção de Energia de Impacto;
Pós Acidente	• Noções de Primeiros-Socorros	• Sistema e-Call; • Extintor de Incêndio; • Kit de Primeiros-Socorros;	• Postos SOS; • Sistemas de Socorro;

Lesson 2: Speed - Road Traffic Crash risk factor

- ➢ 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 5 - Task performance in traffic (infographic)** 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 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).

Teacher presents the **New DLO 1 - 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

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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.

<u>Lesson 3</u>: 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 6 – Field of view (Infographic)**

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 DLO 2 – Field of view, speed impact (simulator).** This DLO will allow students to

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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 3 - 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.

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 4 - 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.

<u>Lesson 4 - Safety equipment - Road Traffic Crash risk factor</u>

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 13 - 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)

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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

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 14 - Crash test without seatbelt and with seatbelt (video)** https://youtu.be/hNw1-OPwiKs
Teacher presents and explains how **New DLO 5 - Crash force calculator (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 7 - How many collisions do you think that happen in a crash accident? (infographic)** 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 15 - Airbag Crash test (video)** [How do airbags work? - YouTube]

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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.

New DER 8 - Collision interval time and pressure (infographic). 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 6 - 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."*

<u>Lesson 5: Distraction and Fatigue - Road Traffic Crash risk factor</u>
<u>Distraction</u>
Students are divided in groups of 4 and the teacher will present and explain **New DER 9 - Attention game (image - calculation sequence + text - with a story + grid – accounting of errors and questions)**
The group members who have the exercise with the mathematical calculation in front of them have 1 minute to solve it (executor). All pupils start at the same time. In the meantime, another pupil in the group will read a story, just once. The aim is to memorize as much information as they can from the story, while solving the mathematical calculation, and then reproduce it.
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?
The teacher asks the students what types of distraction exist and how they interfere with the task of driving or when walking on the street. After the discussion with the support of the **New DER 10 - Types of Distraction (Infographic)** introduces the various types of distraction.
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 DLO 7 - Distraction (Drag & Drop)** should give the definition and explore the concepts of:
- What is attention?
- Selective attention vs divided attention.

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- 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.

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 11 - Fatigue (Infographic)**

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?

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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 8 - 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).

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 12 - Alcohol absorption and elimination (infographic)** 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 9 - Risk of accident and effects of alcohol on the human body (infographic)**

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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.
- ✓ 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 10 - 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).

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<u>**School Research Project**</u>

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 11 - Step-by-step questionnaire on road accident risk factors (power BI)** which includes all the information needed for the different phases of the project development:

- ✓ 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:

- ✓ <u>*First task:*</u> select questions about opinions, attitudes and behaviours concerning road traffic crash risk factors exploring the following website https://www.esranet.eu/
- ✓ <u>*Second task*</u>: 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.
- ✓ <u>*Third task*</u>: 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.
- ✓ <u>*Fourth task*</u>: build an app (online form with Microsoft forms, Google forms, or other) for survey data collection

Teacher together with students and supported by the 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.

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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.
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):

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.

1. Data collection: carrying out the survey.
2. Data analysis: organizing the data and calculating road safety indicators.
3. Produce posters/infographics with main findings.
4. Present the poster/infographic in open schooling event.

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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.

<u>Assessment Questionnaire- Knowledge, Skills, Beliefs, attitudes and behavior</u>
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

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	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 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

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	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.
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.

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	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; **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.

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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; 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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2.4. Institute for Systems and Computer Engineering, Technology and Science (INESC-TEC)

AMENDMENTS

Amendments of the revised version of the educational scenario entitled: *"3D modelling to address pandemic challenges"*

The duration of the sessions was maintained, as well as the respective contents. However, the materials used to present the relevant topics in class were manipulated and more items not initially listed in the scenario's digital educational resources were created and made available. Upon consideration regarding teacher's comments, the resources created to support the educational scenario were revised and improved: made simpler, more direct and concise. Also, the resources were in different cloud drives, and with different associated URLs, which made it difficult for teachers to access and use them. As such, all materials were uploaded to the Photodentro repository and made available freely and on-demand. Thus, we believe that the educational scenario now allows for greater flexibility during the sessions, and enables the teachers to present content more objectively and onpair with the students, according to their needs, backgrounds and skill level.

Amendments of the revised version of the educational scenario entitled: *"3D printing to address pandemic challenges"*

Again, the duration of the sessions was maintained. However, there was a shift in the topics approached in each session. According to the teachers' feedback, and the observation of some classes and its dynamic, we believe it was important to make certain adjustments to the order of the topics being presented. In this regard, some topics changed their place in the sessions, and the activities were therefore also fine-tuned. Logically, the materials used to present the relevant topics in class were manipulated and more items not initially listed in the scenario's digital educational resources were created and made available. Also, the resources were in different cloud drives, and with different associated URLs, which made it difficult for teachers to access and use them. As such, all materials were uploaded to the Photodentro repository and made available freely and on-demand. Thus, we believe that the educational scenario now allows for greater flexibility during the sessions, and enables the teachers to present content more objectively and on-pair with the students, according to their needs, backgrounds and skill level.

Amendments of the revised version of the educational scenario entitled: *"3D animation to address pandemic challenges"*

Again, the duration of the sessions was maintained, as well as the respective contents. As in the previous educational scenario, the materials used to present the relevant topics in class were manipulated and more items not initially listed in the scenario's digital educational resources were created and made available. Upon consideration regarding teacher's comments, the resources created to support the educational scenario were revised and improved: made simpler, more direct and concise. Also, the resources were in different cloud drives, and with different associated URLs, which made it difficult for teachers to access and use them. As such, all materials were uploaded to the Photodentro repository and made available freely and on-demand. Once again, we believe that the educational scenario now allows for greater flexibility during the sessions, and enables the teachers to present content more objectively and on-pair with the students, according to their needs, backgrounds and skill level.

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2.4.1. 3D modeling 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

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real-world objects into a set of data points used to represent the objects digitally.
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.
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

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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.

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- 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

✓ 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</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>

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.

<u>Digital educational resources</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).
6. Introduction of 3D modelling and principles (Powerpoint with infographic).
7. 3D models and environments (videos)
8. Presentation on Basic variables - X, Y, Z (infographic)
9. Show different basic objects to model in 3D (infographic)

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Available resources (link) :
Photodentro Repository (http://photodentro.pafse.eu)

Teaching-learning activities
Lesson 1: Introduction of virtual environments
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?”.

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

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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.

- 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

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- 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.

- 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.

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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.

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.

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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. 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.

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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.

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	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. 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	**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.

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order to decrease inequality and improve inclusion.	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. **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.

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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

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	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. 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.

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	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.
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.

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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.

2.4.2. 3D printing to address pandemic challenges

Main partner responsible
INESC TEC

<u>Context and relevance for public health education</u>

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

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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.
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

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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.

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

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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

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

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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.
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.

<u>Learning goals and outcomes</u>

- ✓ Uses online tools to open and print 3D models.
- ✓ Analyzes pre-designed models.

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- ✓ 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

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

- Introduction of types of printers (*video and PowerPoint*).
- 3D printing tutorial (PowerPoint).
- Printers' basic features: the HARDWARE (*video and tutorial*).
- Printers' basic features: the MATERIALS / SUPPLIES (*infographic and tutorial*).
- Tutorial of how to handle the materials (PowerPoint tutorial).
- Introduction of the printing process (*video and tutorial*).
- 3D post-printing techniques (PowerPoint with video)
- Introduction of the post-printing process (*infographic and tutorial*).
- Questionnaire – quantitative assessment of learnings.

Digital educational resources

- Introduction of the different printing methods (video).
- Examples of printers (video).
- Pedagogical glossary for technical terms and definitions (infographic).
- Different basic objects printable in 3D (infographic).
- Models of 3D printers (video).
- Key factors and features of 3D printers (video).
- Scenarios of use for the materials (infographic).

Available resources (link):

Photodentro Repository (http://photodentro.pafse.eu)

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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.).

- 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.

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.

- brainstorming on the question "What types of 3D printers are there?"

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.

- digital educational resource: 3d printer introduction (video)

Introducing 3D printing by presenting a short video with several examples of printers. Students will raise awareness on printers using the proper hardware. Furthermore, will be presented several videos made

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using different printing methodologies.

- 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.

- 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).

- 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

- learning objects on 3D printing tutorial (video and tutorial)

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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

- Importance of 3D printing

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- 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)

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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 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.

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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. 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?

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	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.
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.

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	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. **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.

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	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.

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	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 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.

2.4.3. 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

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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. 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

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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.
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

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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, 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

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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.
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.

<u>Learning goals and outcomes</u>

- ✓ Uses online tools to 3D animation.
- ✓ Analyzes models.
- ✓ Identifies 3D environments and basic features.
- ✓ Animates basic elements in a 3D environment.
- ✓ Exports animations.

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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

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

- 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

- Introduction of 3D animation (video and PowerPoint).
- Pedagogical glossary for technical terms and definitions (infographic).
- 3D animation and approaches (video).
- Impact of 3D Animation on STEM (infographic).
- Key principles for 3D animation (video).
- Principles for 3D animation (PowerPoint).
- Show different basic objects to animate in 3D (infographic).
- Techniques for moving a 3D camera (video).

Available resources (link):

Photodentro Repository (http://photodentro.pafse.eu)

Teaching – Learning activities (lesson plan/ learning trajectory)

Principal target:

ICT classes.

8th grade (+/- 14 years old students).

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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 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

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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)

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):

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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 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.

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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.

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?

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	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.

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	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. **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.

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	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.

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	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. **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.

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	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. 1) strongly disagree… 5) strongly agree.

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	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.

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	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 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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2.5. Adam Mickiewicz University (AMU)

AMENDMENTS

Amendments of the revised version of the educational scenario entitled: *"Vaccinations - how does the immune system learn"*

In this version of educational scenarios a few changes are introduced which answer the conclusions which arise from evaluations of the scenarios with the teacher. Main idea which arises from them after conducting the scenarios that their first version was too robust and hard to navigate. Also, as anticipated some of the activities were more successful than others. Because of that the activities which should be a priority or recommended by the teachers are highlighted.

Moreover, and necessary theory and introduction is only in the first version of the educational scenario. The idea of the second version scenario is to be "ready to go" for the teacher – which is possible to take quick look on activities, print necessary materials and conduct the lesson.

In each scenario, varieties of activities are proposed, we recommend putting special focus on elements of Inquiry Based Science Education – especially argumentation and project-based learning.

Argumentation is a skill useful for students and teachers. Thanks to it students construct complex answers to the problem which take exceptions into account. That way students are aware of comprehensiveness of the science world, in which one answer is right according to the current knowledge, but it also requires certain circumstances and conditions to be true. This kind of answering is also partially used in national biology exam which makes it even more worthy and applicable to train.

Moreover, projects proposed in the scenarios are perfect opportunity for students to challenge their skill of true scientist. Project based learning gives students great opportunities to be independent in the classroom and learn from their own mistakes. It also gives them more satisfaction from the task which is completed with small or no help of the teacher. All proposed projects in the scenarios are low cost, easy to conduct in the classroom or at home, making them accessible for all of the students despite possible financial constraints.

Recommended activities are highlighted by symbol

Amendments of the revised version of the educational scenario entitled: *"Planet of viruses"*

In this version of educational scenarios a few changes are introduced which answer the conclusions which arise from evaluations of the scenarios with the teacher. Main idea which arises from them after conducting the scenarios that their first version was too robust and hard to navigate. Also, as anticipated some of the activities were more successful than others. Because of that the activities which should be a priority or recommended by the teachers are highlighted.

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Recommended activities are highlighted by symbol

Amendments of the revised version of the educational scenario entitled: *"Different shades of bacteria"*

In this version of educational scenarios a few changes are introduced which answer the conclusions which arise from evaluations of the scenarios with the teacher. Main idea which arises from them after conducting the scenarios that their first version was too robust and hard to navigate. Also, as anticipated some of the activities were more successful than others. Because of that the activities which should be a priority or recommended by the teachers are highlighted.

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In each scenario, varieties of activities are proposed, we recommend putting special focus on elements of Inquiry Based Science Education – especially argumentation and project-based learning.

Argumentation is a skill useful for students and teachers. Thanks to it students construct complex answers to the problem which take exceptions into account. That way students are aware of comprehensiveness of the science world, in which one answer is right according to the current knowledge, but it also requires certain circumstances and conditions to be true. This kind of answering is also partially used in national biology exam which makes it even more worthy and applicable to train.

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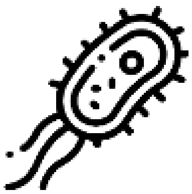
Recommended activities are highlighted by symbol



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2.5.1. 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 topopulation vaccinations, we are unfamiliar with high mortality due to infectious diseases in childhood andsevere 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 toin 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 vaccinatingtheir 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.

Content

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 tohandling 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 andprotection 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 epidemicsand the high death rate from infectious diseases.

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Content glossary

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. stimulatedB 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 orself 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 willinduce 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 moregeneral 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 entirebacterial 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 givendisease 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 byeliminating 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-

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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.

Repeated exposure to the same antigen/pathogen induces a secondary immune response that is much fasterand 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 antygenin less than 24-48h. The process is specific, i.e., it acts on a specific pathogen factors. Specific immunity isdivided 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 recommendedvaccinations 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 languagecan be represented in a formal symbolic language. Instead of natural language, formally defined "arguments" can be made in math and computer science.

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(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). Inits 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 - 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 includedin 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 nocriticism 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 resultsand 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 willingnessto 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 reducethe content of the entire text to its most essential meanings: the most frequent words, key threads, prevailinggrammatical and semantic forms, etc. This method is also used in didactics as a tool that allows you to findanswers to a given question by reducing the content of the entire message to crucial information. It allowsyou 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

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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). Thisdescription 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 argumentsfor why they would be productive and the best person to have in a team, company, or project. An elevatorshowcase doesn't have to cover all of these but usually at least explains what an idea, product, company, orperson 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

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 thesefundamental 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 meaningfulto 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 studythe 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. Someof 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 Ustaand Ültay (2016), McClure, Sonak and Suen have emphasized that concept maps can be used as a learningstrategy, 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

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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 formof 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 centralidea, showing connections between the main concept and specific details. These elements can be presentedin the form of images, formulas, or experiment sketches. Images or sketches are most often represented incolor. 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 thatis 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 andits 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 adequateselection of arguments and counter-arguments. Its course includes:

- 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 toexpress his opinion.
- Summary - both sides summarize all the speeches. They can provide answers to the counter-argumentsof 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 adoor. 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 morethan 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 studentslearn 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 theknowledge to solve problems, the problem is presented first. PBL assignments can be short, or they can bemore 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

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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 thesignificant 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 theviewer 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:

- 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 moreclearly 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 andgrammar of their own.

<u>Competences / Learning Goals</u>
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.

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Skills

a) General skills: critical thinking, reflective thinking, problem-solving, decision making, collaboration andcommunication 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.

Attitudes (Affective domain)

a) Attitudes and values: appreciation of vaccination – positive meaning of it for society, appreciation of thevital 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' personalvalue 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.

<u>Classroom organization requirements</u>

All special classroom organization requirements are proposed below directly in the lesson's activity.

<u>Prerequisite knowledge and skills</u>

- Microbial nature of contagion by communicable diseases.
- Examples of historical and modern cases of epidemics and pandemics – viral and bacterial diseases andhow vaccinations helped with protection before them.
- Fundamental hygiene rules as pharmaceutical interventions with the use of vaccination.
- Ability to interpret infographics.
- Ease in making digital presentations.
- Ease in constructing an argument.

<u>School research project</u>

<u>Topics and inquiry processes</u>

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 notmatch 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 dothey 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)?

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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 aschool 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 ofdoing only the chosen activities from the scenario which answer to the needs of their group.

Digital Learning Objects (DLOs) and Digital Learning Resources (DERs)

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

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how the immune system adapts, dendritic cell 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, animationhttps://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 vaccineshttps://vimeo.com/227180098
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

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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.

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

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- model building
- Content analysis

RECOMMENDED ACTIVITIES: 2,3

THE COURSE OF THE LESSON:
Activity 1
What does the term I am immune mean?
The students in groups create a definition, and then in the classroom, they discuss which one is the best.
Introduction to the immune system - what does it give us?
Creation of a mind map representing the immune system's role - answering the question: what do we have thanks to it, and how is it provided?.

**Activity 2**

What factors influence the likelihood of contracting infectious diseases? Students analyze infographics and articles and then develop a 10-point guide on how to support the immune system.

- age

Decrease in the number of memory cells with age.

- sometimes sex
- obesity

Immunosuppressive effect of adipose tissue. Adipose tissue strengthens inflammation and reduces/delays the response of immune cells to the pathogen.

- diet:

https://www.mp.pl/pacjent/dieta/wywiady/90034,od-czy-zalezy-odpornosc

- lifestyle (e.g. getting enough sleep)
- genetic factors
- stress

Which of these factors can we influence and which are not?

**Activity 3**

Problem question: What can we do to limit the spread of infectious diseases?

A common reminder of infectious diseases.
Brainstorming on proposals for measures to reduce the spread of infectious diseases?

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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)

In 1854, a cholera epidemic broke out and resulted in 616 deaths in London's Soho.

Doctor John Snow was skeptical about theories that the epidemic was caused by "pestilential air" or miasms. The 'germ theory' that various microorganisms cause diseases has yet to be delineated and established in society.

Dr. Snow collected the data in the district - he took the addresses of those who died, the number of deaths in each location, and entered this data into a table.

Snow then mapped the data onto a map of the Soho neighborhood. The results were surprising.

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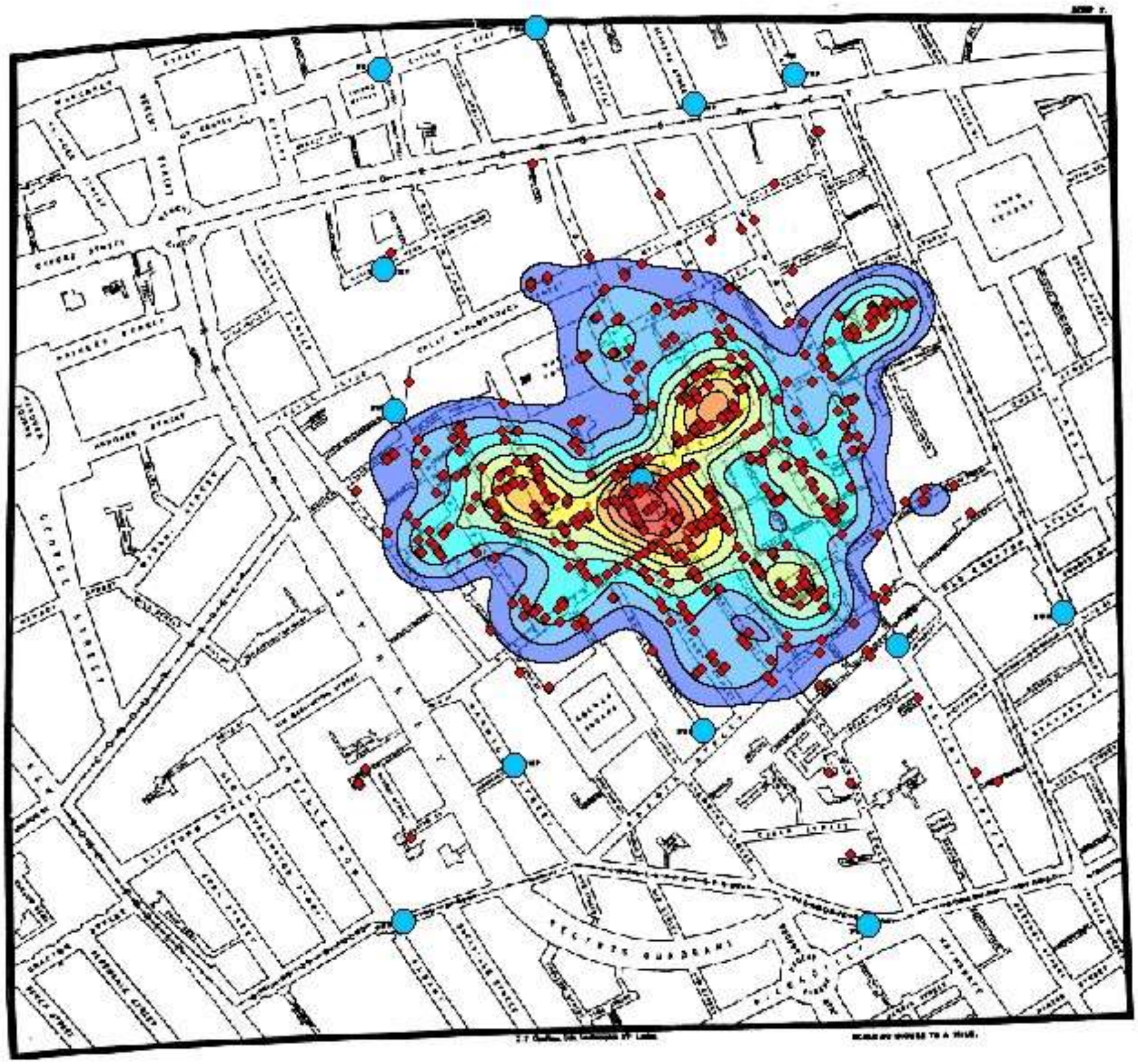

The locations of the water pumps are marked in blue, while the area with cholera cases has been marked in colour. In red - the cases of houses with the highest number - to the purple area - with the lowest number of cases of this disease. The remaining single cases are marked with a red dot. The location of the water pumps is marked with a blue dot.

Questions for students:

Is the distribution of cholera cases even across the city? Justify your answer.

What conclusion can you draw from the presented data?

He noted that most of the deaths were concentrated in the Broad Street pump area of the city.

Snow noted that the Broad Street pump contained low-quality water and was highly likely to be a source of contamination. With this information, Dr. Snow went to the city authorities.

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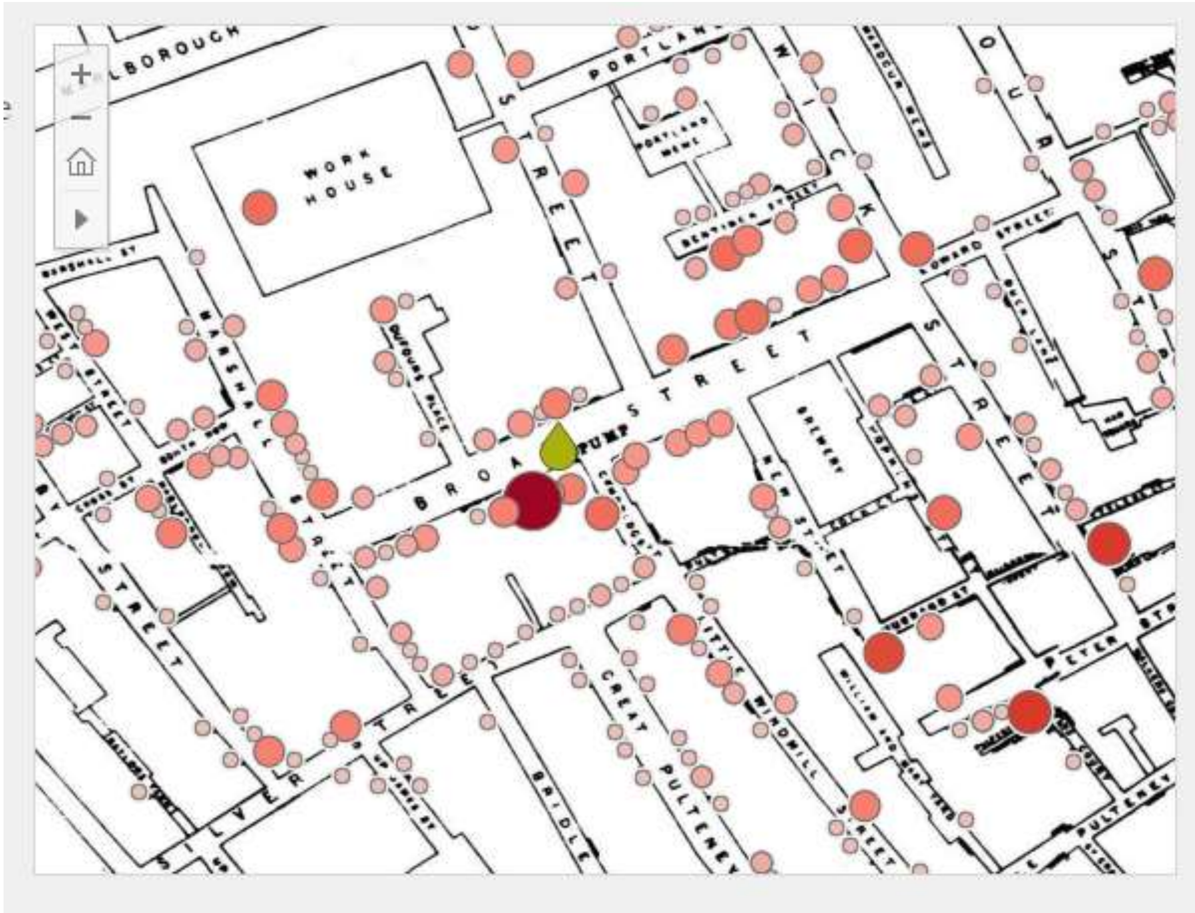
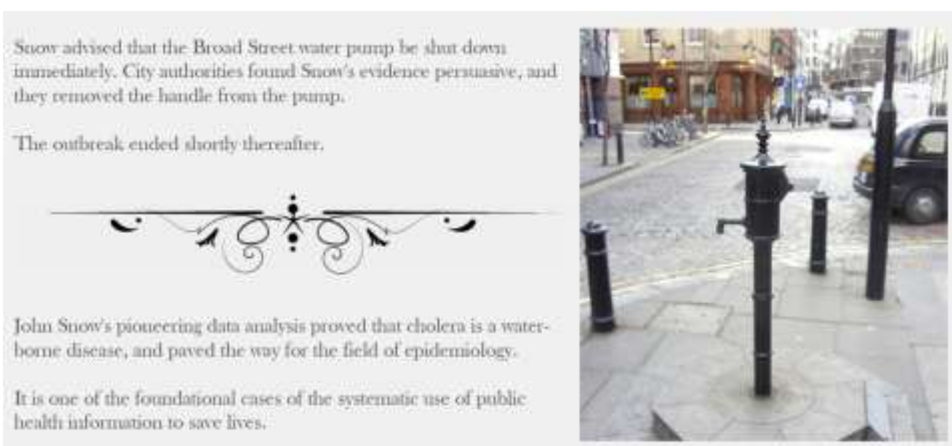


City officials found Snow's arguments compelling and shut down the Broad Street pump. Not long after, there was a decline in infections and deaths caused by cholera.



Question for students:
What measures could the people of London take in 1854 to prevent the spread of the cholera epidemic?

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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

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 news
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.

THE COURSE OF THE LESSON:

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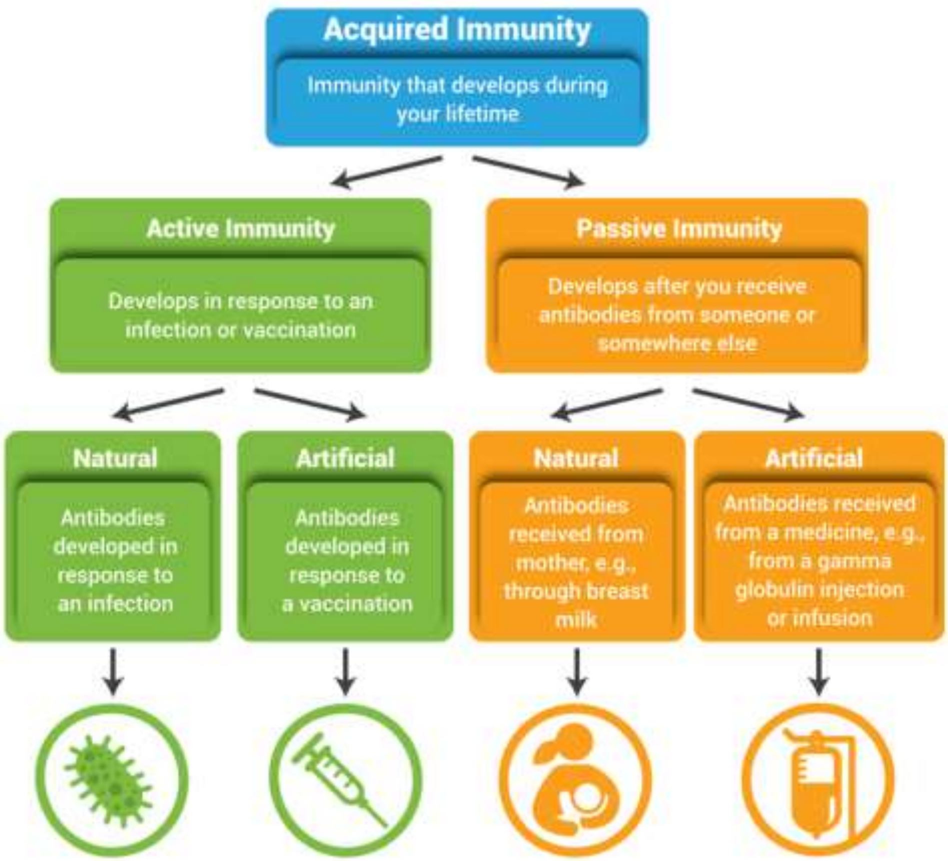
Activity 1
Students create a definition of antigen and antibody, then watch an animation on this:
https://www.youtube.com/watch?v=_N1xX49AqwQ

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
Types of immunity - what are they?
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.
Sample diagram:



Lesson 3-4 Vaccines - What Are They?

OBJECTIVES
In terms of knowledge
Student:

- lists the types of vaccines,

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- 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

RECOMMENDED ACTIVITY: 2

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 (hygiene - washing hands, face masks, disinfection, washing fruit before consumption, boiling water, etc.)
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.
Materials:
What is a vaccine?
Vaccine - is a biological preparation that stimulates the immune system to fight a given viral or bacterial

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pathogen. Vaccines have a significant impact on human health: they reduce the symptoms of infection and improve the quality of life.
How do I get the vaccine? What are the types of vaccines?
Types of vaccines (depending on the method of antigen preparation):
1. Conventional vaccines:
1.1. Attenuated viruses
1.2. Inactivated viruses
2. Recombinant vaccines (new generation)
  2.1. Recombinant viral (subunit) proteins
  2.2. Recombinant viruses
  2.3. Replicons
  2.4. DNA vaccines
3. Vector vaccines (p. COVID-19 - adenoviral vector - AstraZeneca, J&J)
4. mRNA vaccines (p. COVID-19 - Pfizer, Moderna)

Live attenuated ("weakened") virus vaccines - are obtained using cell/tissue culture. In this way, less virulent strains of the virus can be obtained. Reduction of virulence is also performed by targeted mutagenesis of virulence regions or by deletion of genes responsible for virulence. The replication capacity of the attenuated virus is significantly lower in vivo than that of the wild virus strain. The attenuated virus leads to infection with a much milder course than the wild-type strain with high virulence. Attenuated vaccines are rarely used nowadays as pathogen can easily regain infectious capacity, resulting in evading the host's immune system.

Inactivated virus vaccines are obtained by chemically inactivating a virulent virus. Viral pathogens are grown under controlled conditions, and chemical inactivation lowers the virulence/infectivity of the virus. Since inactivated viruses cause a weaker immune response, chemical compounds (adjuvants) are additionally used that interact with the virus to induce immunity. Additional injection doses are also used.
Vaccines containing recombinant viral proteins - use recombinant viral protein as an immunogen. Since vaccines are effective because they are effective at producing antibodies that recognize one or two viral proteins, it is often not necessary to use the whole virus. They contain the antigen, or fragments thereof, produced by genetic engineering.
Viral recombinant proteins must maintain the conformation necessary to induce the synthesis of specific protective antibodies. Vaccine examples: papillomavirus (HPV), and hepatitis B virus.
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
What are the ingredients of the vaccines - analysis of what are the preservatives and how much?
Components of vaccines
Antigen
Adjuvants
aluminum hydroxide,
aluminum phosphate,
calcium phosphate
paraffin oil

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Preservatives
Auxiliary and stabilizing substances
Ad 3. Preservatives and auxiliary and stabilizing substances

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

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,
- 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

RECOMMENDED ACTIVITIES: 1,2, 4

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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? Here are some insights that may make it easier to understand - cognitive biases:

- understanding the essence of science / or not understanding the essence of science and its cumulative nature (that it is variable and that it gives us the best possible explanation at a given moment)
- cherry-picking - selecting such information that supports the adopted thesis and omitting those that prove otherwise
- anecdotal evidence - referring to individual cases that are not presented in context, concerning other data, are not scientifically verified (like a friend of my mother ...)
- false equivalency - the feeling that after reading several sources of information (most often websites), you have enough knowledge to feel like a specialist in a given field
- apparent controversies (manufacturers)
- conspiracy theories - link to the conspiracy theories manual https://www.climatechangecommunication.org/wp-content/uploads/2021/12/ConspiracyTheoryHandbook_Polish.pdf

Moreover:
Vaccination is a victim of its success - because vaccines are very effective, the decline in the number of people who get sick and die due to a given disease is so significant that people stop seeing the ill or dying around them and stop fearing the disease. Often, when they are no longer afraid of the disease, they stop vaccinating because they do not see the point.

Activity 3

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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

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?
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/
What does the occurrence of a VAE depend on? A VAE is a result of:
- a health problem coincidentally occurring at the same time as vaccination;
The individual response of the vaccinated person to the vaccine;
- an incorrect vaccination technique;
- a defect in the vaccine due to poor storage.
Considering the above information, explain why a medical consultation and medical examination are necessary before administering the vaccine.
Question to Pupils:
What are the consequences of VAE 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.
Is medicine interested in VAEs?
Yes - because it provides information on the effects of a vaccine and influences decisions on its possible withdrawal.
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-

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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
What is herd immunity, and when can we achieve it?
The number of susceptible people in the population must be immunized against a given pathogen to limit the spread of infection and eliminate the infectious agent from the environment (eradication).
Calculation of the R-factor for various diseases - what is this factor, and what depends on it.
Basic reproduction number / R0 - the theoretical number that expresses how many more people an infected person can transmit an infectious agent to, assuming that each contact is a contact with a susceptible person. It does not take into account immunized people. It is not a constant value for the pathogen and depends on many factors, including environmental conditions and dynamics of a given population. It allows us to determine the dynamics of the spread of the disease, which is particularly important during an epidemic. It enables you to determine how many people need to be immunized to achieve herd immunity. If the index is more than 1, one patient infects more than one person, and thus the epidemic is still developing.
When the R0 coefficient is below 1, it is a sign that the epidemic is dying out, and fewer and fewer people are getting infected by each other.
In general, the higher the R0, the more difficult it is to control the situation, and more people must obtain immunity to eliminate the infectious agent from the environment.
Factors influencing R0 are:

- The duration of infection in the subject.
- Infectivity of the virus/microorganism.
- Population density (potential number of contacts).

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.

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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 9
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
The role of understanding probability in conscious decision making.

Assessment methods

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 approvedfor 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 usuallycases 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 introducedfor 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 secondinitially 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 hasbeen 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 diseasefrom 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

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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
artificialSolution
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 andan 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. 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, earlydetection 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 asick person who spreads tuberculosis with coughing or sneezing. They are aerobic bacteria, resistant tomany environmental factors, such as: drying, high and low temperature, high and low pH. Mycobacteriaattack and develop in various human organs, incl. in the lymph nodes, skin, lungs, bones,

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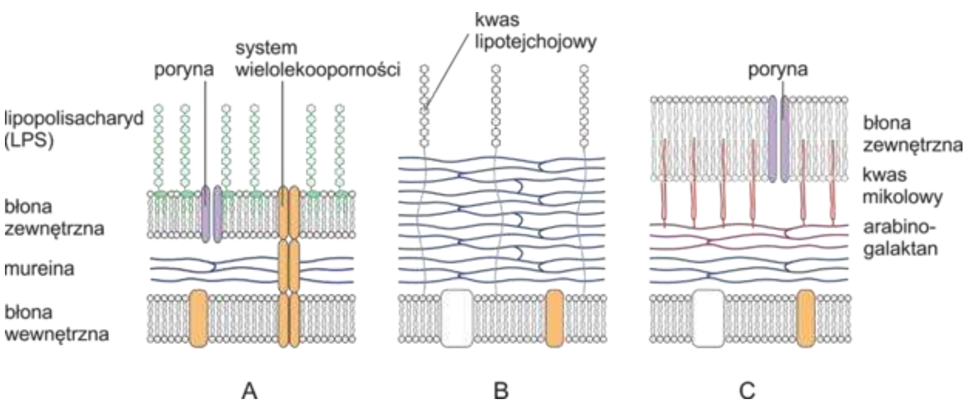
brain and kidneys.Name the human organ in which tuberculosis bacilli develop most often. Justify your answer. Organ: Justification:

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 commoninfection 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 severeform of tuberculosis, tuberculosis meningitis. However, only a fraction of the studies have shown that the vaccine is effective



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 FSolution: PPF

SUMMARY

Experts (students) review articles from the Internet, catching fake news on social media, etc.Links:

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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) andvirologists.

Students during the scenario will have opportunities to work with STEM professionals. Also as a follow upstudents 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 precautionsare 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 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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2.5.2. Planet of viruses

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 educationproject-based educationopen 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 fromemployees' 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 pathogenson 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?

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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 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, asymptomaticcases, infectivity, healthcare system capacity and the epidemic curve, which are commonly referredto 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.

Content

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.

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Antigen - anything capable of triggering an immune response
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 seenby 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 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.

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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 beeasily lost. In particular, factors damaging its effectiveness are, for example, the presence of a very strongdominant 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 changethe 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 wherethere 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 canfind 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.

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 tosolve 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

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IBSE – inquiry based science 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 processesin 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 questionsthat are meaningful to them (e.g. generated from their own experiences) and with the explicit aim to developcoherent knowledge and rigorous understanding of phenomena, as well as understanding of how scientistsstudy 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 doingand 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 beseen 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).
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 theeye" as possible by using visual effects (Abi-El-Mona & Adb-El-Khalick, 2008). Mind mapping is used inorder 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

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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 adequateselection 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 througha 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 beshort, 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 engagein 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, B. (2010). *Teaching at its best: A research-based resource for college instructors* (2nd ed.). SanFrancisco, 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 aproject," 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

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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
- Metacognitive knowledge about the modeling process: explicit description and reflection on the major steps of the modeling-based cycle
- 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 conceptor 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 codessuch as flow charts, networks, and sign languages employ symbols that may be remote from their visualreferents, with a vocabulary and grammar of their own.

WANTED - Arrest warrant - a method of describing an object, taking into account its characteristic

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features, problems caused by a given object, etc. The idea of a wanted poster, known even from literature, is used here.

Competences / Learning Goals

Knowledge (Core Concepts)

Transdisciplinary concepts: scientific modelling, graphs in science.
Specific content concepts: communicable diseases, epidemic, pandemic, disease transmission route, viruses, viruses' cycles, vaccination, viral diseases

Skills

General skills: critical thinking, reflective thinking, problem solving, decision making, collaboration and communication within small groups, presentation skills.
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.

Attitudes (Affective domain)

Attitudes and values: appreciation of biodiversity of viruses', appreciation of their meaning on the levelnot 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 empathizingwith scientists in terms of the complex nature of their work and the necessary decision making, upgradingof the position of science in students' personal value systems, comprehension of the role of discussion and disagreements within the scientific community.
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

What is the virus?
Viruses - their simple structure and complex relationships.
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

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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

The rest of the class, maybe teachers and students of the entire school proving the project is presented at a school event.

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, sciencewithin 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 doingonly 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
Principles of the Oxford debate - infographic
Argument structure - infographic
Features of dead and living matter of viruses - infographic
What is life - infographic
Features of animate matter - infographic
Structure of viruses - infographic
Various virus shapes - infographic
Lytic and lysogenic cycle - infographic
Features of dead and living matter of viruses - infographics
Argument structure - infographic
Principles of a SWOT analysis - infographics
Virus wanted poster rules - infographic
Sample wanted poster - infographic
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

What is life – a long version (up to 1h) Extended version – what is life:
https://www.youtube.com/watch?v=_z-SUo2wP4IWhat is life?

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https://youtu.be/QOCaacO8wus Definition of life:
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 wasdamaged.
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
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

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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=tMTI3gU0mFc&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/

<u>Teaching - learning activities</u>
Lesson 1-2 - What is the virus?
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

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RECOMENDED: ACTIVITY 4

THE COURSE OF THE LESSON:
The main dilemma - are viruses alive or not?

Activity 1
The lesson begins with the presentation of fragments of films about what life is (it is recommended to watch only fragments of the film in the class - and the whole film before class)
An introductory film about the life
- extended version (after an hour or more) in English
https://www.youtube.com/watch?v=_z-SUo2wP4I
- what is life?
https://youtu.be/QOCaacO8wus - what is life?
Analysis of the content of articles:
An attempt to write a definition of life - based on personal knowledge and watching the movie. 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.
- Problem "n = 1" - how do we know what life should look like since we know only one kind of life - a life that exists on Earth. All living things are likely descended from a single LUCA ancestor. Could life from a different source be completely different?
A problem to consider in the discussion - why define life? Many scholars and philosophers consider this problem artificial, and it is unnecessary to deal with it. Yet a definition of life is needed in areas such as astrobiology (the search for extraterrestrial life), synthetic biology (an attempt to create artificial living organisms), and evolutionary biology (an attempt to understand the origin and origins of 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
Concerning the created definitions of life, it is worth considering what features animate and inanimate matter has. Then it is worth testing the truth and usefulness of the proposed definitions based on examples of the so-called borderline cases in class discussions.
Examples of borderline cases:
- sterile organisms (e.g., silt)
- intracellular parasites - rickettsiae, chlamydia
- anabiosis (a state of extreme decline in the vital activity of the body, usually in response to adverse environmental conditions)
- abiogenesis (a natural life process taking place in non-living matter, e.g., inorganic compounds);

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- simplified endosymbionts - mitochondria and plastids
- artificial life / artificial intelligence / empathic robots
- xenobots
- viruses
- computer viruses

One of the welcome conclusions from the discussion should be the message that it is not always easy to distinguish between the animate and the inanimate from a biological point of view. We must have several criteria.

Activity 3

Compare the definitions given by the students with those given by the scholars:
"Life is a self-sustaining chemical system capable of undergoing Darwinian evolution" [Joyce 1994] - Questions that could be asked when presenting this definition: How do you know what meets your requirements and what does not? What does "self-supporting" mean? Can parasites or adulterous organisms live "by themselves"? Or maybe life is a system of all organisms that cannot be separated. What does "evolve" actually mean?
"A living organism is an autopoietic system" - they can reproduce themselves (copies of themselves) and their parts. Questions that can be asked when presenting this definition: But what about the evolution and variability of organisms? Are the robots producing robots alive? Are there "superorganisms" such as swarms, societies, etc.
"We define life as a set of self-sustaining (autopoietic) objects capable of evolution by natural selection" "a living individual is a network of negative feedback (regulatory mechanisms) serving the superior positive feedback (potential for expansion)" - Questions that can be asked while presenting this definition: Is life a learning process?
At this point, it is also worth referring to three life systems and three basic levels of the organization of living matter:
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.
The three basic levels of the organization of living matter include:
* Cell level:
-metabolic system: autocatalytic biochemical processes of the cell
-information system: DNA and gene expression mechanism
-compartmentalization system: cell membrane, cell wall, cytoskeleton
* Body level:
-metabolic system: digestive system, respiratory system, circulatory system
-information system: the nervous system and the endocrine system
-compartmentalization system: skin, immune system, musculoskeletal system
* Superorganism level:
-metabolic system: food exchange systems, group hunting
-information system: interpersonal signal systems, social hierarchy, pheromone systems
-compartmentalization system: territories and borders.

Activity 4

Distinguishing features of living and inanimate matter.
We begin our 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?

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- multiplication (difference with multiplication?),
- evolution (?),
- metabolism - Erwin Schrödinger "Metabolism is the ability to lower the level of its entropy (disorder) at the expense of the entropy of the environment (Schrödinger 1998)."
- homeostasis (maintaining the right conditions inside the cell to function),
- reacting to stimuli,
- construction organization (cellular, tissue);

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
The basic structure of the virus
A. Non-enveloped viruses. B. Enveloped viruses
1. Kapsyd
2. Nucleic acid
3. Capsomer
4. Nucleocapsid
5. Virion
6. Lipid sheath
7. Insets
- they are made of only DNA or RNA and proteins that surround them (some also have a lipid envelope),
- they do not move,
- obligatory intracellular parasites - they cannot produce energy by themselves and do not have their metabolism, and their replication (duplication) takes place only inside the living cells of another organism,
+ take control of a cell, creating something like a new organism, the sole purpose of which is to reproduce the virus and thus "reproduce" (in this case, more often referred to as multiplication)
+ infected cells can receive and respond to signals necessary for viral replication. Some viruses can even "communicate" by passing a signal from one infected cell to another. This is how viruses regulate their multiplication strategy,
+ viruses evolve like other life forms. They are subject to natural selection, recombination mutations, etc.

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
ARGUMENT STRUCTURE

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
"You could almost say that viruses cycle between being alive, when chemically active and reproducing in host cells, and not being alive when existing as chemically inert viruses outside a cell." Paul Nurse. What

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Is Life? New York: W. W. Norton and Company, Inc. 2021

Lesson 3-4 Viruses - their simple structure and complex relationships.
OBJECTIVES

In terms of news:
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,
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.

Methods
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

RECOMENDED ACTIVITIES: 4,8

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. Through this activity, we stimulate students to present and visualize their current ideas about viruses, which can be rebuilt during subsequent activities during the lesson.

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.

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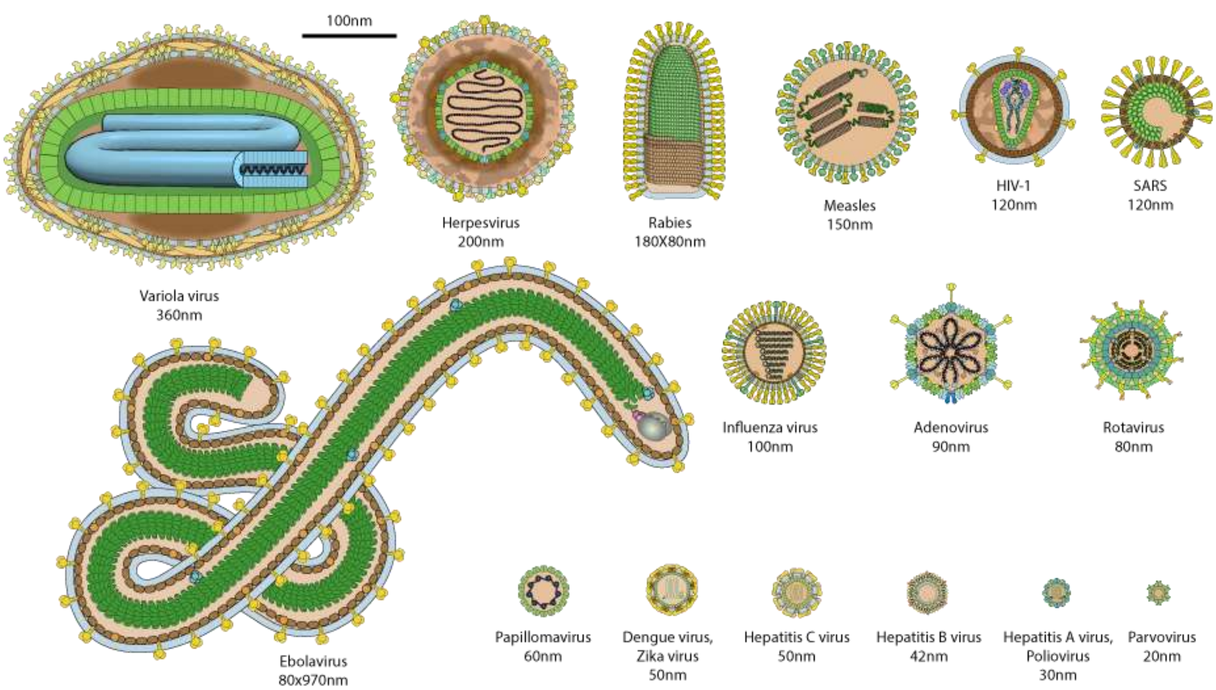
Key idea: Viruses exist EVERYWHERE; there are living organisms that can infect. They are the most numerous biological creations in the world. Their number is vast, and it is estimated that there are 1031 of them on Earth, which is over a trillion times more than people. We observe them in the sea, air, soil, and the bodies of all living things. There are many more in our body than our cells (but they are much smaller than them, so they account for a small part of our mass). Fortunately, most of these viruses aren't just infecting us by microorganisms in our gut, on our skin, etc. Viral DNA.
We know that viruses are the most numerous formations in the Earth's biosphere and that a significant number of them are found in the oceans - they are mainly phages. Each group of organisms has "its" viruses. So in that sense, they are everywhere. Of course, the discussion may be towards man and viral diseases, but it is good to know that viruses have coexisted / co-evolved with all organisms since the dawn of life on Earth.
Where shouldn't they be? In places that should be sterile - e.g., inside our organs. But not always; for example, in 2009, Dana Willner examined what viruses can be inside our bodies. Until her research, the lungs were considered more or less "sterile." The researcher verified this hypothesis and described 174 types of viruses found in human lungs, of which only 10% were known to science. This can be explained by the contact of the lungs with the air we breathe. However, there are other organs in our body that, by assumption, do not have such contact and should be sterile, such as the brain.

Activity 3
Problem question: What do the different types of viruses look like?
Key information: Presentation of the diversity of virus structure,
- examples of various viruses,
- genetic material - DNA or RNA,
- capsid - the protein coat that protects the viral genome, often contains proteins that interact with the surface of the host cell (with sites called viral receptors), allowing them to attach to it and then get inside (molecular "pick")
- some viruses have a lipid envelope, which is usually a fragment of the host's membrane along with the viral proteins



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The virions of some of the most common human viruses and their relative size. Nucleic acids are not to scale. https://en.wikipedia.org/wiki/Virus

Task:
Design a virus model
This activity can be done in collaboration with your math teacher.
The command is: Based on the analysis of the drawing showing the structure of the virus, construct your virus - assembling the virus model (with DNA, capsid, glycoproteins, spikes, etc.). (the difficulty is creating a composite grid to show the structure of viruses)
Supporting materials
- Variety of virus structure

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.
Required materials:
aluminum foil
double-sided tape that stays sticky when wet
butter
butter knife
a small plate
topping for the cake (waxy, elongated)
bowl
hot water
paper towel
soap
spoon
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

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

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the cell nucleus
Białowieża Primeval Forest
Now compare your answers with the scale of the universe
https://scaleofuniverse.com/
Will you improve your list now?
Correct order and size of objects:
Atom 10-10 m
Coronavirus - 9-12 nm (nano = 10-9 m)
Colon bacteria (approx. 2 μm long and approx. 0.8 μm in diameter)
Cell nucleus 3.5 - 20 μm (μm = 10−6 m)
Sperm (human six μm long, the finch itself is 26 μm long)
Ovum (approx. 0.12 mm in diameter, mm = 10−3 m)
Liver - 22-24 cm in the transverse dimension, 15-20 cm in the longitudinal dimension and 12-15 cm in the antero-posterior dimension; cm = 10−2 m
Białowieża Primeval Forest - 3,086 km^2 - a kilometer is 1000 meters
Indian Ocean - 70,560,000 km^2
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.

Activity 7
The main problem: How do viruses survive in cells? Life cycle
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).

Life cycles of viruses
Viruses can multiply (replicate) in a more or less harmful way to the cell. The easiest way to replicate is through the lytic cycle. In this cycle, the virus enters the cell and quickly takes control of it - it changes its metabolism to produce copies of it. These changes are so dramatic that most of the proteins produced by a cell during an infection are often associated with the virus's multiplication. There is no longer enough energy or nutrients for the cell's normal functioning. As the name suggests, the lytic cycle ends in lysis, i.e., death and cell breakdown. Sometimes a cell bursts under its pressure. The duration of the cycle may vary, but some viruses (e.g., bacteriophages, i.e., bacterial viruses) can complete replication only tens of minutes after penetrating the cell. It is doubtful whether viruses that kill their host so quickly can be called parasites. Some researchers argue that one should rather talk about predators in such a situation.
The lysogenic cycle is different. Viruses that reproduce in this way integrate their genome into the host's DNA after entering the cell. There they stay "dormant," and their genetic material (called a provirus) is copied as a "stowaway" as the cell replicates its DNA. In this way, daughter cells inherit the viral genes as if they were their own. This condition can persist for generations - many genomes have traces of viruses incorporated so long that they have degenerated and lost their ability to reproduce independently. Under certain conditions, a dormant viral genome can be reactivated, i.e., provirus induction. This happens when the cell is under stress (e.g., starvation or radiation). The viral genome is 'cut' from the host DNA, and replication begins, which resembles a lytic cycle.

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Many viruses only go through a lytic cycle, and others can enter both the lytic and lysogenic cycles. How they multiply depends on the condition of the host cell. However, there are no viruses that replicate only in the lysogenic cycle (in such a situation, virus particles would never be produced).
Some viruses can persist in an infected cell without producing daughter particles. This condition is called latency, or the latency of the virus in the cell. This is a lysogeny-like condition in bacteriophages. During the latency, the viral genome is present in the cell, but the expression of its genes is minimal. In this state, mainly proteins are produced that maintain the latency. It is also characteristic that the latent infection persists in the cell despite the action of the host's immune system. The latency capability is only characteristic of some viruses, such as the herpes simplex virus (HSV-1). These viruses can remain in the human body for many years without showing clinical symptoms of infection. Under certain conditions, however, the virus can reactivate and produce daughter virions (so-called productive infection). Typically, latent infection only occurs in certain cell types, such as in HSV-1, mainly cells in the central nervous system, and EBV in some immune system cells. The reactivation of a latent virus can occur under the influence of many factors, e.g., decreased immunity, hormones, solar radiation, infection with other pathogens, or other stress.
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.
Suggested information on general strategies for viruses to survive in host cells, which students can write:
some viruses have a life cycle of 20 minutes, after which the affected cell is no longer alive;
other viruses act like terrorists - they completely change the metabolism of the cell - they fall as if through a window (receptor) and force the cell to slave labor - in such a way that all cellular resources serve the purpose of the virus - e.g., at the beginning of an attack on a cell there are about 2% of virus RNA, just before cell death, it is already around 98%)
lysogenic cycle and copying the genetic material of the virus along with the genetic material of bacteria,
simple structure of viruses,
virus latency in host cells,
covering itself with the host's cell membrane, making it difficult for the immune system to detect,
binding to receptors on the surface of the host cell and penetration of the virion inside.
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:
https://pl.khanacademy.org/science/biology/biology-of-viruses/virus-biology/a/bacteriophages

Activity 8
Definitions of key terms:
1. a Parasite is a form of antagonistic coexistence of two organisms, one of which benefits from the coexistence, and the other suffers damage. This term is used in biology - concerning two organisms of different species - and in sociology, where parasitism is called the idle lifestyle of a person able to work (from Wikipedia)
2. Parasitoids - organisms parasitizing other organisms (e.g., insects, plants, mites), sometimes killing their

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host. Sometimes the term parasitoid is a temporary parasite. They are organisms intermediate between predators and parasites, entering into antagonistic interactions with another species (larval parasitism). Then the parasitoid (insects, mainly from the order of flies and hymenoptera) lays its eggs in the body of an insect of another species. The larvae are parasites - they feed on the host's body without depriving it of life before pupation. Unlike most predators, parasitoids can be highly specialized. Parasitoids are used for biological pest control. (wikipedia)
3. Predation is sometimes defined as a way of eating organisms, using the body of another animal as food and, unlike parasitism, leading to the death of the victim. In ecology, it is treated as one of the antagonistic forms of interspecies (predator-victim) or intraspecific (e.g., cannibalism) relationships that developed in the course of coevolution (adaptation). Predator-victim systems and systems related to other interspecies interactions determine the distribution, balance, and structures of ecosystems (wikipedia)
Task:
In the light of the presented definitions, determine which ecological group the viruses belong to and construct an argument supporting your position.

Lesson 5-6 Pathogenicity - virus vs. immune system
OBJECTIVES

In terms of news
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
Student:
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
Student:
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

RECOMMENDED ACTIVITIES: 2, 3, 4, 6, 8

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.

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Principles of work: Students (first individually) create definition cards of two concepts - health and disease, and stick their definitions on two sheets of paper (separate definitions of health and disease). 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.
Key ideas:
A disease is a disorder of function or damage to the body's structure. A disease occurs when the action of the pathogenic agent causes undesirable symptoms that differ from the functions of a healthy organism. https://pl.wikipedia.org/wiki/Choroba
According to the definition by the World Health Organization - Health - is a state of complete physical, mental and social well-being. In recent years, this definition has been supplemented with the ability to lead a productive social and economic life and a spiritual dimension. Health is a pervasive issue.
We distinguish between physical, mental, emotional, social, and spiritual health. For an extended reading: https://pl.wikipedia.org/wiki/Zdrowie

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.
Key ideas and terms:
Virus virulence/virulence - The ability of a virus to cause disease in an infected host.
Viral infections often occur seasonally and cyclically. They depend on:
- the transmission pathway through which the virus spreads,
- periodic fluctuations in the host's immune defense,
* The incidence of viral diseases also depends on:
- individual predispositions, build, gender, etc.
* Viral pathogenesis is how a viral infection leads to disease.
Viral pathogenesis is an abnormal situation with no value for the virus. Most viral infections are subclinical. It is not in the "interest" of the virus to severely damage or kill the host. The consequences of viral infections depend on the interaction between many viral agents and the host.
The immune response to the virus is possibly the most influential in influencing the outcome of an infection. The virus is completely cleared from the body and completely healed in most cases. The immune response cannot completely remove the virus in other infections, and the virus persists. The immune response plays a significant pathological role in the disease of many infections. Overall, cellular immunity plays a major role in clearing up a viral infection, while humoral immunity protects against reinfection.
* Paths of movement and spread of viruses:
- droplet pathway (e.g., influenza virus)
- digestive tract (fecal-oral route) (e.g., rotavirus)
- genitourinary system (sexual route) (e.g., HIV)
- direct route - by contact with mucous membranes (e.g., herpes virus)
- from an infected mother to the fetus via the placenta
- mediated by a vector from another person (e.g., animal) (e.g., dengue virus)
- blood-borne route (e.g., during blood transfusion) (e.g., HIV, HBV, HCV)
vector-mediated contact with the reservoir (e.g., tick-borne encephalitis virus)
Recommended additional materials:
Integrated Educational Platform
Keyword: Human viral diseases - types of infections, prevention, and treatment

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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

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

Activity 4a An additional form of activity recommended for teachers.

Materials prepared for students in the form of printed information about viruses and viral diseases should be covered with foil and sprayed with water with dissolved powder - Fluorescein 200% (dye with approval). Using a UV flashlight at the end of the lesson, we can track how much the students spread the "virus" around each other.

Required materials:

- wrapped information about viruses

fluorescein 200%

water

UV flashlight

plastic bottle with an atomizer to distribute the dye solution

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.

The wanted poster should contain the following information:

Virus Name:

Virus Photo:

Characteristics:

Route of spread:

Description of contact with the virus (symptoms):

Viral diseases worth paying attention to are rabies, AIDS, Heine-Medina, diseases caused by HPV infection, influenza, measles, smallpox, rubella, mumps, hepatitis A, B, and C, some types of cancer;

Additional information on rhinoviruses

Rhinoviruses (from the Greek rhino - nose) is a simple virus whose genetic material (RNA) has ten genes. They are the most common viral infectious agent in humans, responsible for 30-50% of colds (Wikipedia). The virus spreads by airborne droplets (it quickly penetrates the droplets of liquid thrown out when sneezing or coughing). If you don't wash your hands, for example, when you touch a handkerchief, the virus spreads to everything you feel. If someone else touches it, they also have virions of this virus on their hands. After getting into the nose, rhinoviruses attach to the epithelial cells inside the nasal passages. Penetrating inside them, they force the epithelial cell to produce its genetic material and its proteins. The affected cell eventually ruptures (it is lysed), and new virus particles attack other cells or come out with

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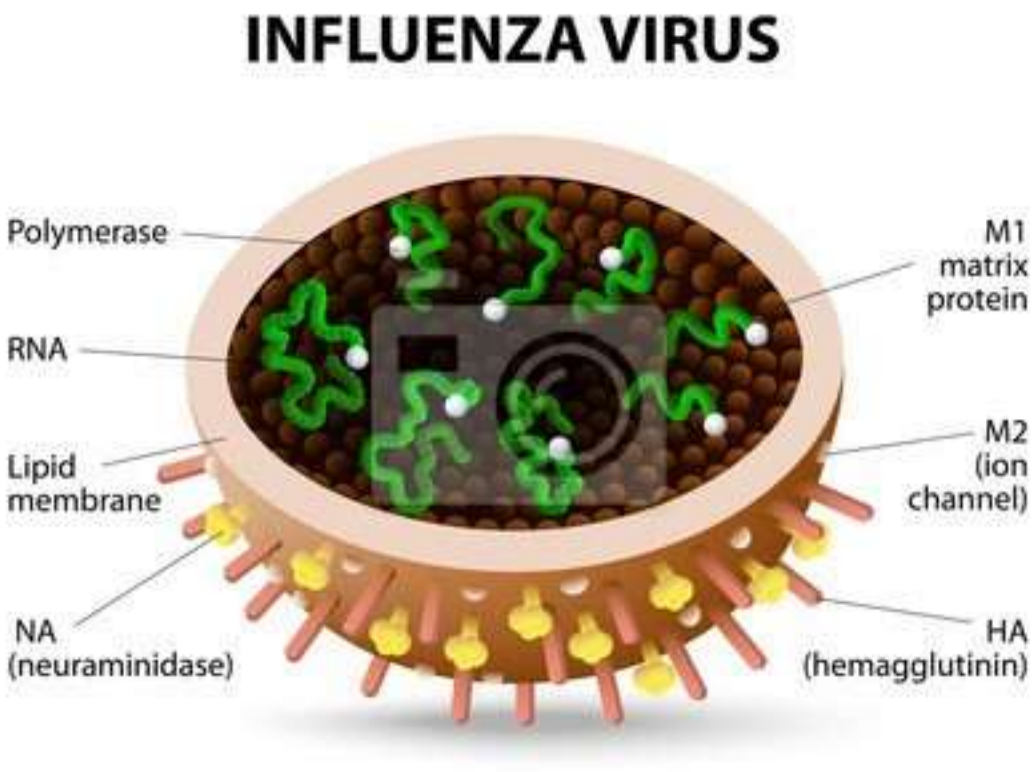
liquid droplets when sneezing. As a rule, they strike a few cells - our malaise is caused by cytokines and the immune system's reaction. Since the epithelial cell produces new virus particles, it often makes mistakes; it is very variable and changes (mutating) rapidly. These changes cause our immune system to struggle to recognize the new versions of the virus (and not have the antibodies ready). As a result, even after one year, we can be infected by several different strains of rhinovirus, among others; for this reason, we still do not have effective medicines for colds - a runny nose treated lasts a week, untreated for seven days - there is something in it. (based on The Planet of Viruses by C. Zimmer).

Additional information about the group virus
Flu - "influential disease" (influenza in Italian means influence, the name derives from the fact that in the Middle Ages, there was a belief among doctors that the stars influenced patients' health). It is estimated that this virus attacks one billion people on Earth every year, and as a result of this attack, from 290,000 to 650,000 people die each year. Hippocrates already described it in 412 BCE. In 1918, there was an epidemic of this disease, which took 50 to 100 million people, which constituted 3–5% of the world's population. The genetic material of the influenza virus (RNA) has only 13 genes. Still, it is also characterized by a large genetic variability mainly related to mutations, such as the effect of carelessness in reverse transcriptase, which transcribes viral RNA into DNA. The virus's genetic material is contained in a lipid-protein envelope (nucleocapsid). The core consists of a nucleoprotein from RNA, and it is surrounded by the M protein, which is surrounded by a lipid envelope. The casing contains highly immunogenic glycoproteins haemagglutinin and neuraminidase.



The virus spreads by airborne droplets. When it gets into the nose or throat, it attacks the epithelial cells of these organs - it sticks to epithelial cells and penetrates inside. It forces cells to produce their genetic material and their proteins. The cell is lysed and destroyed, and new virus particles attack new epithelial cells that face the same fate. The flu usually passes after a few days due to the immune system, which

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produces antibodies that attack the virus's surface proteins (the virus uses these proteins to attach to cells and penetrate epithelial cells). Unfortunately, antibodies targeting one type of virus are not effective against the next version (resulting from a change in the virus's genetic material). This virus can spread through the respiratory system and "get" even to the lungs, weakening the natural defense mechanisms (destroying epithelial tissue) paves the way for other pathogens, thus leading to complications and lung infections. In such a situation, pathogens cross the lung barrier and spread throughout the body - or selected places in our body. This virus is so variable that new variants appear every year, so to protect themselves against it, people are willing to vaccinate themselves every year. Other animals, such as birds, are carriers of this virus strain. In these animals, the virus can, for example, attack the intestines, not the respiratory tract, and leave the bird's body together with the feces. Thus, it is a source of infection for another bird (e.g., how the droppings end up in the water). Sometimes the avian version of the virus attacks the human body. Most of these infections are harmless because the bird flu virus has different properties, and their set "does not work" in the human body. Most often, it also cannot spread from person to person. The situation changes when such an avian virus mutates. (e.g., as a result of an antigenic jump, the genetic material of the bird version is mixed with the genetic material of the human version, the resulting "hybrid" is potentially a much greater threat to our health). (Adapted from Planet of Viruses by C. Zimmer)
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 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

Swine foot-and-mouth disease	
Virus	https://pl.wikipedia.org/wiki/Wirus_pryszczycy

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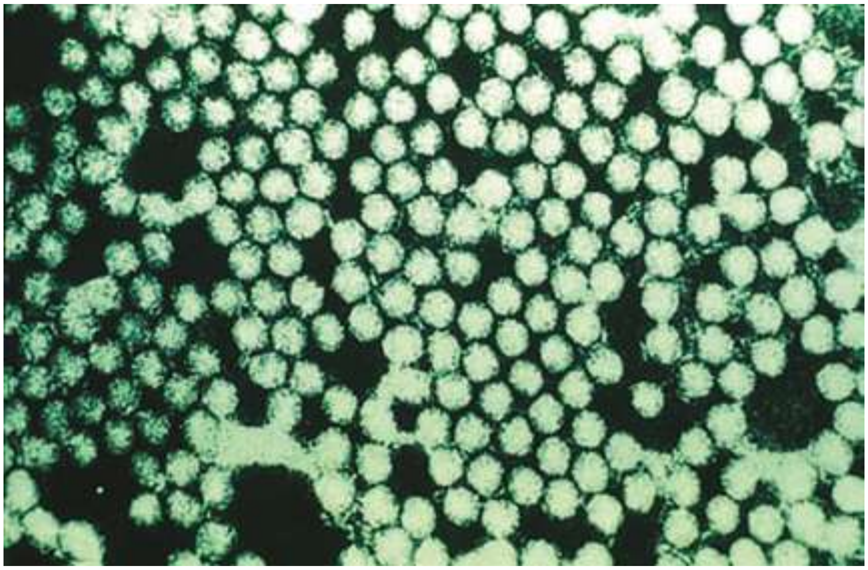
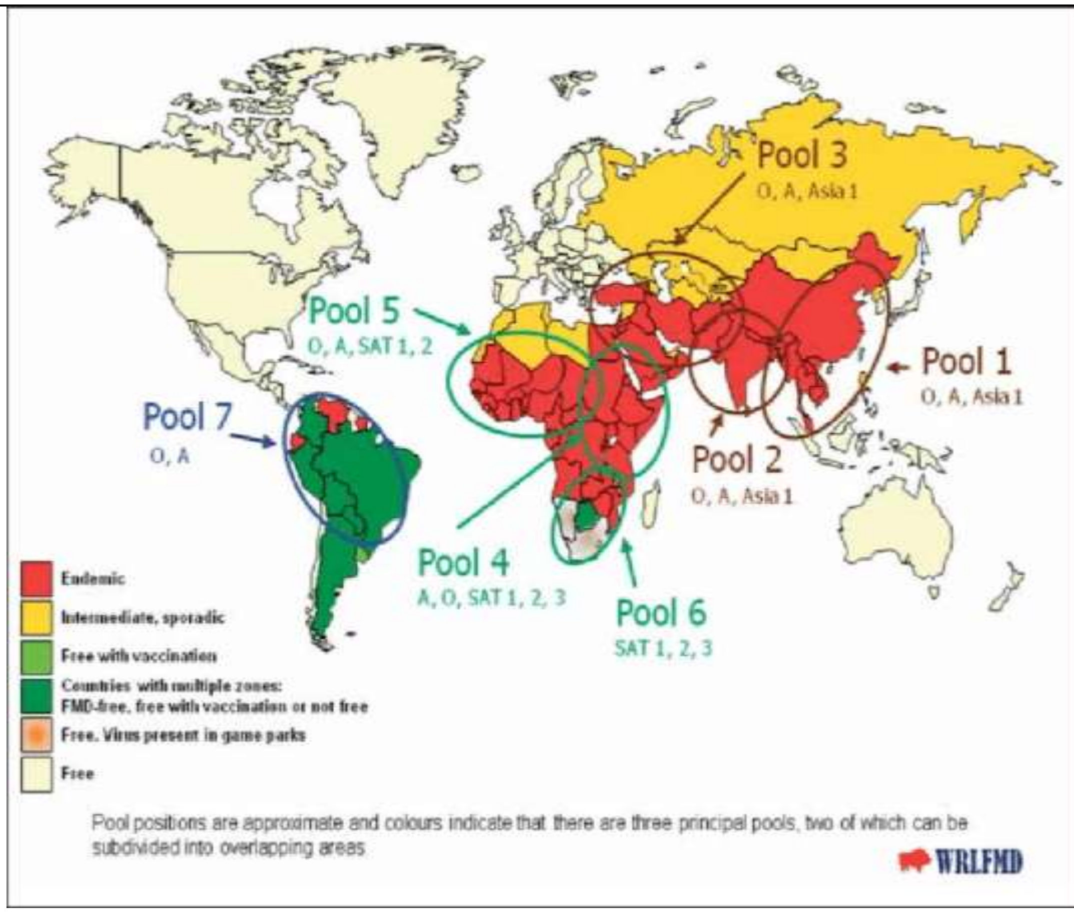
	
Map	
Losses	This paper estimates that annual impact of FMD in terms of visible production losses and vaccination in endemic regions alone amount to between US$6.5 and 21 billion. In addition, outbreaks in FMD free countries and zones cause losses of >US$1.5 billion a year
Description	https://pl.wikipedia.org/wiki/Pryszczyca Foot and mouth disease [a]) - acute, very contagious viral disease of farmed and wild animals. In the European Union, including Poland, it is subject to notification and fight

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	against ex officio. It occurs all over the world. Currently considered the most dangerous disease of animals, its occurrence paralyzes world trade in animals and animal products. Its occurrence causes very large economic losses. Cattle, pigs, sheep, goats, buffaloes, reindeers, camels, wild boars and wild ruminants are susceptible to the infection. Susceptibility to infection varies within the same species. https://www.wetgiw.gov.pl/nadzor-weterynaryjny/o-pryszczycy About foot-and-mouth disease, the ways of infection and the protection of animals against disease Foot and mouth disease (FMD) is an infectious and contagious disease of domestic and wild cloven-hoofed animals. Cattle are most susceptible to infection, followed by pigs, sheep and goats. The disease is caused by a virus of the genus Aphtovirus belonging to the Picornaviridae family. The country where FMD occurs is exposed to very large economic losses in the meat industry and breeding. These losses are caused by the deaths of animals from susceptible species, the costs of eliminating disease outbreaks and compensations paid, as well as the suspension of trade and export of animals from susceptible species, meat of these animals and products obtained from these animals. Humans are susceptible to infection, however foot-and-mouth disease in humans is not fatal and is usually mild. People become infected through direct contact with a sick animal, as well as by consuming meat, milk and unpasteurized dairy products from an infected animal. Dear infection The virus is excreted by the infected animal before it develops disease symptoms. Infected and sick with foot-and-mouth disease animals shed the virus in the exhaled air, in their secretions and excreta. The greatest concentration of the virus is found in the serum fluid and epithelium of emerging blisters. Animals can carry the virus for up to three years. Sources of infection: sick or stored animals, saliva, milk and its products, feces, fodder, water, mangers, floors, pastures, leather, wool, hands and clothes of the operator, meat and its products, semen and embryos, means of transport, rodents, birds, insects, kitchen waste. Protection of animals against disease In order to protect the herd from the entry of the foot-and-mouth disease virus, it should be remembered that the animals entering it come from a known source and are accompanied by a health certificate confirming their origin and health status.
Source	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3989032/

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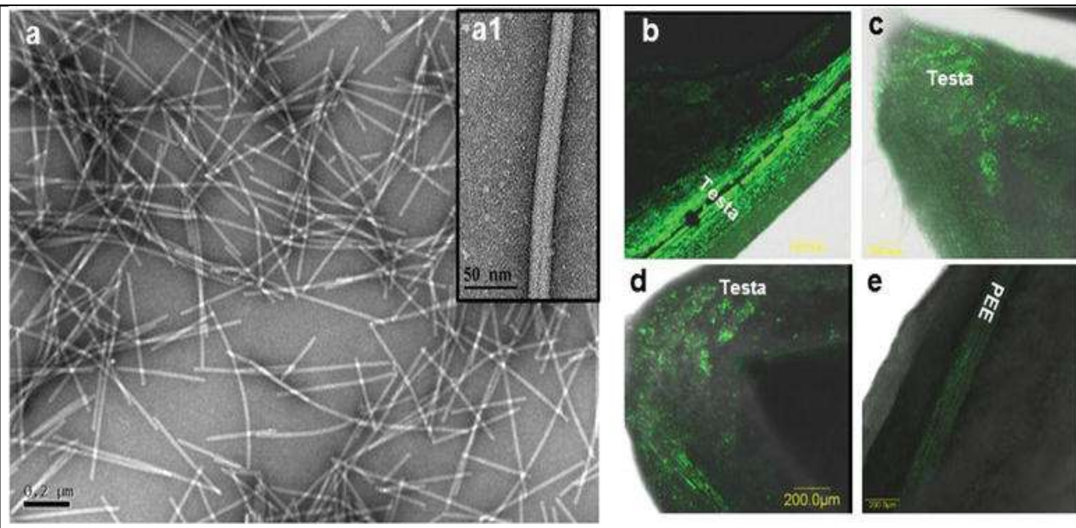
Cucumber green mosaic virus	
Virus	
Distribution	CGMMV is a virus classified as Tobamovirus. It was first described in 1935 in Great Britain. In the years 1935–2006 it gradually spread throughout Europe. Its presence was found, among others in: Denmark, Germany, Russia, Finland, the Netherlands, Ukraine and the former Yugoslavia. In the years 2007–2021, the virus spread strongly in countries where it was previously observed and reached South and East Asia. It was also recorded for the first time in Poland. In 2013–2021, it reached Canada and the USA in North America, as well as Australia. Currently, it is found on all continents except South America.

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	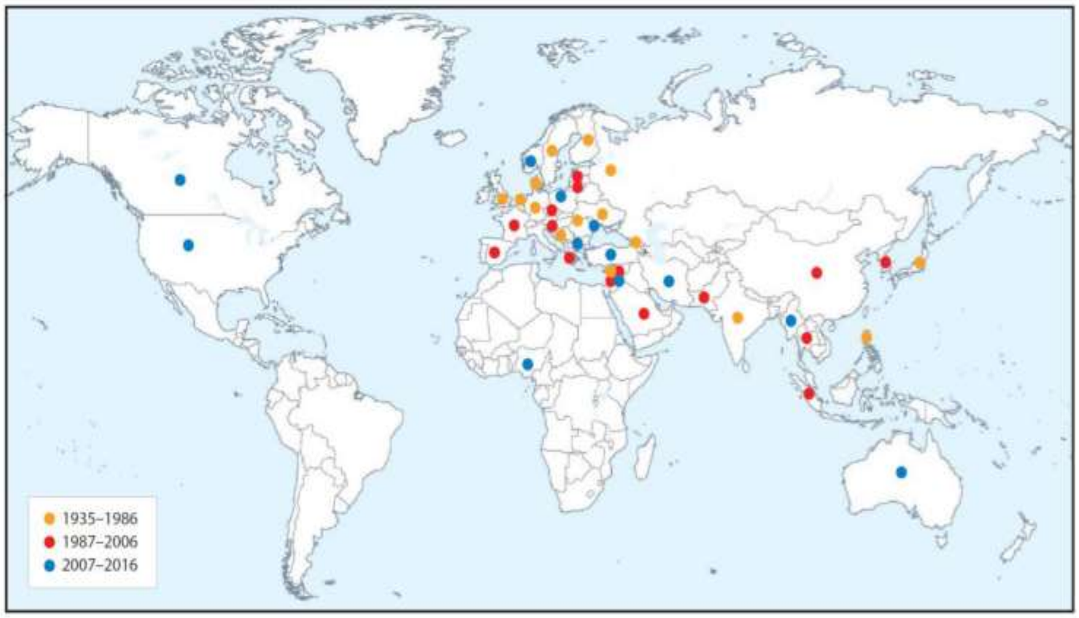 (A)
Losses	“Yield is reduced by 25% even more if no control actions are taken into account. In the epidermis of the sick plants characteristic structures can be seen easily with a microscope.”

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	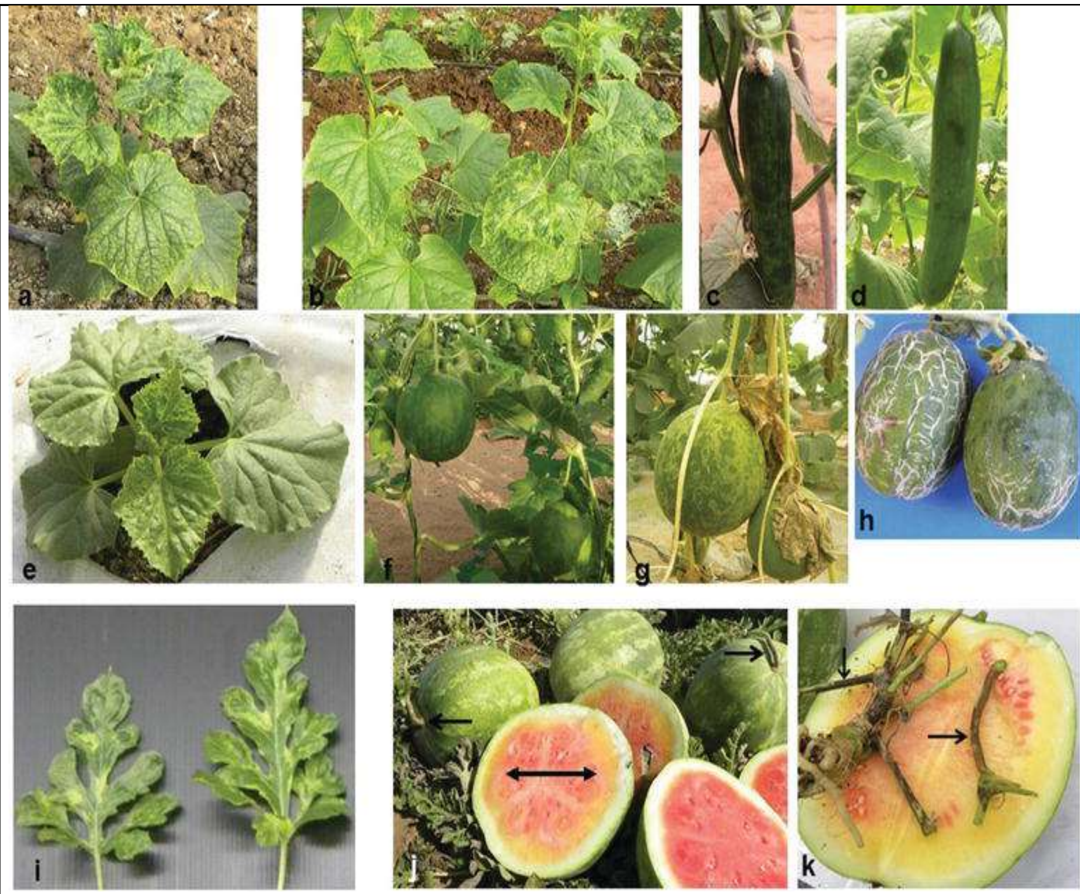
Description	Cucumber mosaic virus (CMV) is a common plant virus that is transmitted by aphids and causes large yield losses of various crops each year. The virus produces a protein called 2b that attacks the plant's immune system, allowing the viral infection to spread. The symptoms of CGMMV infection are fairly easy to identify. The leaves have characteristic light and dark green mosaic-like spots, moreover, bubbles are formed on them and the leaf blades are deformed. Plant growth is stunted, the buds may die and sometimes the fruit may become distorted, although symptoms vary depending on the variety. Often the symptoms disappear as the leaves age. When infection occurs on young plants grown under high light conditions, they may wilt. These symptoms are easily confused with Pythium soft root rot, but with viral infection, the roots are healthy and leaf wilt is most evident in the center of the plant. Low temperature and light intensity in spring intensify the symptoms.
Source	https://www.warzywa.pl/warzywa-pod-oslonami/czy-wirus-zielonej-mozaiki-ogorka-cgmmv-jest-zagrozeniem-dla-polskich-upraw/

In the packages, the map of the occurrence and spread of the virus, the historically proposed fighting methods - choose one of them and then have to trace which was effective.
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.

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Additional materials:
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.
The scatter pattern is below.

SWINE FLU	A/H1N1	Infectious respiratory disease in pigs. In humans, infection with the virus occurs through direct contact with an animal. On June 11, 2009, WHO announced the highest threat level, representing a pandemic. More than a year later (August 10), the World Health Organization announced the end of the pandemic. The disease symptoms are high fever, headache, sore throat, muscle aches, runny nose, diarrhea, confusion, and loss of consciousness.
Chickenpox	herpeswirus 3 HHV-3	Human is the only reservoir and source of the virus. Infection occurs through droplets and direct contact. The hatching period of the virus is 10-21 days, and then the virus multiplies - the effect is the involvement of the skin and the appearance of characteristic blooms. The recurrent (secondary) form is shingles.
MUMPS	MUMPS VIRUS	A viral disease that mainly affects school-age children. The infection occurs most often in winter and early spring. The droplet route is widened or through the saliva on the food. Very often, there are no symptoms of the disease. In the asymptomatic course, swelling of the parotid glands may occur, causing pain when opening the mouth or biting.
RUBELLA	RUBELLA VIRUS (WIRUS RÓŻYCZKI)	Infectious disease of childhood, spread by airborne droplets. Surviving the disease causes permanent immunity. Red spots appear on the skin during the illness, which eventually merges into one (red skin feeling). Lymph nodes grow in size and are painful to touch. Wounds appear in the mouth.
AIDS	HIV	The final stage of infection with a virus transmitted through contact with the patient's blood or mucosa (e.g., using the same needles, sexual contact). The immune system is wiped out, leading to numerous diseases (called indicator diseases) - e.g., mycoses, pneumonia
MEASELS	MEASELS VIRUS	Childhood rash disease. The infection spreads through droplets - the virus enters the body through the nasopharynx. A characteristic feature is a whitish discoloration appearing on the mucosa of the cheeks, and there is a pink rash.
HEINE - MEDINA DISEASE	POLIO VIRUS	The virus enters the body via the fecal-oral route. The disease is usually asymptomatic. The full-blown disease leads to disturbances

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		in the nervous system, which causes disruptions in skeletal muscle innervation and muscle atrophy.
RABIES	RABIES VIRUS	The route of infection is direct contact with the saliva of an infected animal. The name derives from the course of one of the most discernible forms of the disease, which is characterized by excitement and aggression (rage). Both wild and domestic animals are a reservoir of germs. The virus travels to the nervous system from the site of its invasion (e.g., the wound). Examples of symptoms are drooling and hydrophobia.
SEVERE ACUTE RESPIRATORY SYNDROME	VIRUS SARS	The primary host is Chinese grace. The first human disease occurred in 2002 in China, and then the disease spread to other Asian countries, finally reaching other countries of the world by air travel. The infection is usually caused by droplets but also through contact with the feces of a sick person. Initially, the symptoms resemble flu, but the shortness of breath occurs in the latter stages of the disease (connection to a ventilator is necessary).
VARIOLA VERA	VARIOLA VIRUS	Human is a reservoir of the virus. The infection occurs through various routes: by droplets, contact with lesions on the patient's skin, bed linen of a sick person, or medical equipment. Viruses travel to the lymph nodes, spleen, and marrow. A characteristic symptom is a rash that turns into scabs that fall off, leaving unsightly scars. The last natural case of the disease was diagnosed in 1977 - it is the only human disease recognized by the WHO in 1980 as completely eradicated.
HEPATITIS A	HAV	The so-called food jaundice. Infection occurs through the gastrointestinal tract, contact with the patient's secretion, and infected products—dirty hands disease. The disease symptoms are vomiting, abdominal pain, anorexia, and low-grade fever.
HEPATITIS B	HBV	The way of infection is direct contact with the sick person (their body fluids). Most cases are self-healing. However, the chronic condition can lead to jaundice, cirrhosis, and even death.
HEPATITIS C	HCV	Infection is a result of direct contact with the patient's blood. The characteristic symptoms are fatigue, nausea, and weight loss. Jaundice occurs in the acute phase. In 80% of those infected, the disease becomes chronic, and cirrhosis and liver cancer may develop over many years.

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.

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Analysis of the content of the article:
Antiviral drugs and interferons:
https://bioinfo.imdik.pan.pl/coronavirus-service/mesmerize/leki-prawywirusowe/
Key ideas:
Flu and interferon - medicine worse than the disease? Why do we use antiviral drugs less frequently than antibiotics against bacteria?
Students construct a decision tree in an attempt to resolve this dilemma.
Designing new and effective antiviral drugs is difficult because viruses multiply inside cells using cellular enzymes, organelles, and macromolecules. For this reason, antiviral preparations must be precise to the virus and should not harm the host. Unfortunately, with many antiviral drugs, side effects often occur. Most antiviral drugs are designed to act as an essential step in replicating a particular virus. Therefore, they are usually only effective against the specific virus and viruses closely related. Antiviral drugs often target viral enzymatic proteins with properties different from cellular proteins, such as reverse transcriptase, integrase, or particular proteases.

Assessment methods
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
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.
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; theirgenetic materials may be mixed - there is an antigenic jump) mutations (Antigenic shift - a phenomenon ofgenetic 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

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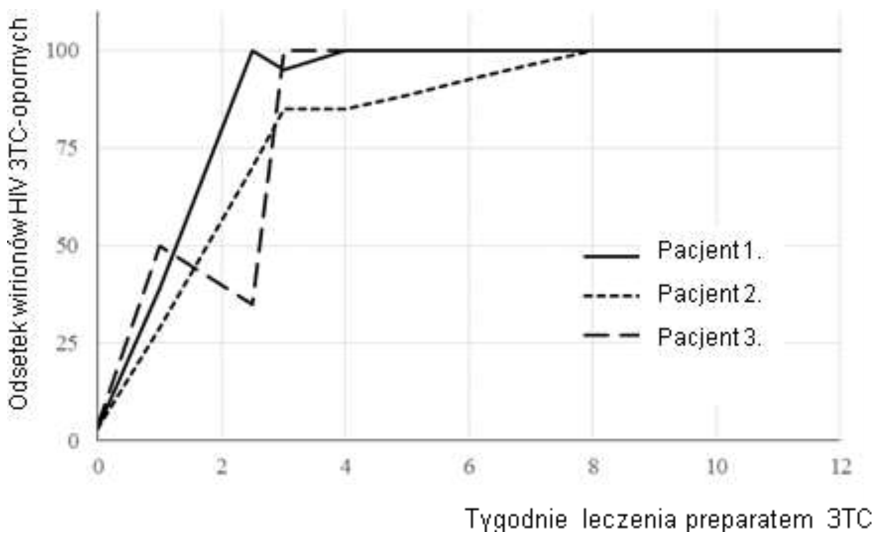
https://en.wikipedia.org/wiki/Antigenic_shift#/media/File:AntigenicShift_HiRes.svg
Regarding the phenomenon of the antigenic jump, explain why a new strain of influenza (swine flu) posed a risk to people who came into contact with this virus.
Show what the 1918 flu epidemic had in common with that of 2009.
Explain why scientists cannot predict whether new emerging viruses will be "mild" or "virulent."
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

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.
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.
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,

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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
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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2.5.3. Different shades of bacteria

Main partner responsible
Adam Mickiewicz University, Poznań, Poland

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 dangerousbacterial 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 biogeochemicalcycles and the processes of fermentation and rotting. As symbiotic organisms, they enable the digestion offood 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 humanfunctioning 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 toin 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.

Content
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 a prokaryotic cell, taking into account the differences in the structure of the cellwall

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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.

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 hasfallen 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

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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. Thestudy 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.

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 theresident 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

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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 beeasily lost. In particular, factors damaging its effectiveness are, for example, the presence of a very strongdominant 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 changethe 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 wherethere 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 canfind 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 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 processesin 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 questionsthat are meaningful to them (e.g. generated from their own experiences) and with the explicit aim to developcoherent knowledge and rigorous understanding of phenomena, as well as understanding of how scientistsstudy 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.

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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 theeye" as possible by using visual effects (Abi-El-Mona & Adb-El-Khalick, 2008). Mind mapping is used inorder 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

Microscopy is the technical field of using microscopes to view objects and areas of objects that cannot beseen 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 adequateselection 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 througha door. Nowadays, in other cases, the most common vote is by show of hands.

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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 studentslearn 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 setaside 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 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
Metacognitive knowledge about the modeling process: explicit description and reflection on the major steps of the modeling-based cycle
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 oridea. drawing, and the related visualisation that results from drawing, helped children to construct meaningfor themselves as well as share their ideas with others and across contexts.

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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 asflow 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

Knowledge (Core Concepts)

Transdisciplinary concepts: scientific modelling, graphs in science.
Specific content concepts: communicable diseases, epidemic, pandemic, disease transmission route, bacteria, bacteria communication, antibiotics, antibiotic resistance, bacterial diseases

Skills

General skills: critical thinking, reflective thinking, problem solving, decision making, collaboration and communication within small groups, presentation skills.
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.

Attitudes (Affective domain)

Attitudes and values: appreciation of biodiversity of bacteria, appreciation of their meaning on the levelnot 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.
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:

What is bacteria? Do perfect bacteria exist?
Incredibly small, incredibly numerous, but as clever as parasites - About bacteria that cause disease.
Life of bacteria under a magnifying glass - What is it like to be a bacterium?
Microbiome - how many humans and how many bacteria are in you?
Bacteria - enemy or friend?
Bacteria in court.

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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 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 themicroorganism 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 aschool event.

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 onlythe 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

Gram bacterial cell staining method - infographic
A computer game - drag and drop to build a bacterial cell
Bacterial cell structure - infographics
Comparison of bacteria and archaeobacteria – infographic
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."

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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
Microbiome – infographic
Argument structure – infographic
Prebiotics and probiotics – infographic
Human map - the possibility of an interactive page with the marking of the places of occurrenceof bacteria
Interesting facts about human microbiota - infographics under the slogan: "did you know that ...
The distribution of bacteria in your home - infographic
Principles of creating a concept map - infographic
Ways of using E. coli by humans – infographic
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/DbGhwjCPAAutotrophs and Heterotrophs 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

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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/

<u>Teaching - Learning activities</u>
Lesson 1 - What is bacteria? Do perfect bacteria exist?
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,
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

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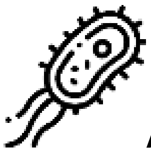
RECOMMENDED ACTIVITIES: 1,4

THE 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).

Key task:

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.

Links to sites with images of bacteria:

https://pl.wikipedia.org/wiki/Bakterie

https://www.e-biotechnologia.pl/Artykuly/Budowa-bakterii

The opening question for the next discussion: When did the first bacteria arise? Are all bacteria an evolutionarily uniform group?

Another question: What is LUCA? (Last universal common ancestor) - the last universal common ancestor and relative of all living creatures on Earth.

(purpose is to determine the differences between proper bacteria and archaea - comparison of structure and physiology)

Bacteria are divided into two main lines of development.

Bacteria	Archebacteria
(including cyanobacteria)	
- they have peptidoglycan in the cell wall	- they have no peptidoglycan in the wall
- in their chromosome (DNA) there are exclusively cellular coding fragments	-there are also non-coding fragments in their chromosome - DNA is discontinuous
	- they are probably more closely related to eukaryotes than to bacteria
	- there are numerous extremophiles

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here they live in extreme conditions,

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,

Equipment of the cell necessary for adhesion - a bacterial cell must have fimbriae, pilli, enzymes to attach to anything - this is an advantage for the bacteria - it can thus draw nutrients from the host or from the surface on which it is located. In addition, pilli enable the exchange of genetic material between bacterial cells - which increases their adaptability, enables the acquisition of new features (e.g., resistance to antibiotics) Fimbria: https://szkolnictwo.pl/test,4,3794,18,Bakterie-pierwsze_organizmy_na_Ziemi-Fimbrie

Communication among bacteria. Communication is also an element of pathogenicity (an element of chemically occurring communication, e.g., Vibrio fisheri - which shows the phenomenon of bioluminescence (shines), and the emission of light is closely related to the concentration of the population of these bacteria in the body of an organism in symbiosis with them (eg squid)). Bacteria use a rich system of chemical diffusion signals as language. There are many signal substances, signal detection systems, and mechanisms for processing and transmitting them in the bacterial world. Controlling and coordinating these processes increases the chances of bacteria survival in their ecological niche. For communication to take place and to be effective, however, there must be an appropriate number of microorganisms communicating with each other. A bacterial quorum refers to a situation in which a sufficiently large number of bacteria are accumulated in a given environment for the process of communicating through the language of chemical substances to take place. Achieving quorum facilitates collaboration, and quorum sensing means the operation of a system designed to communicate that controls the expression of specific genes in response to population densities.

A large layer of mucus surrounding bacterial cells is a mechanism of pathogenicity (the bacterial shell consists mainly of water and polysaccharides). A dense layer of this type of substance attached to the surface of a bacterial cell is called the envelope. It is difficult to wash off the cell surface, and the watery discharge that adheres freely to the cell surface is called mucus. Mucus can be easily rinsed off the cell surface. In a liquid environment, it often spreads to the ground. This layer provides bacteria with:
protection against drying out, against viruses and substances toxic to them, against phagocytosis, against macrophages and antibodies (hindering access to it),
regulating the absorption of various substances into the cell,
are involved in ensuring the adherence of bacterial cells to various solid surfaces, e.g., to animal tissues or plants acting as hosts,
can support the mobility of bacteria,
they help certain species of bacteria to keep individual cells in clusters,
polysaccharide compounds with adhesive properties take part in the formation of a biofilm.

genetic material and ribosomes - they give bacterial cells not only the ability to carry out their metabolism but also, for example, the ability to produce toxins - bacteria often have some form of "weapons," "missiles" that could fire at a eukaryotic cell, which could damage these missiles a eukaryotic cell and release

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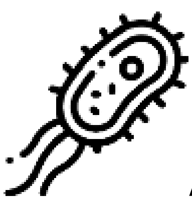
nutrients from it (mainly toxins that make holes in the host cells

the possibility of improving your weapons - conjugation - recombining genetic material - also for fimbria and pili

typical features of a bacterial cell - such as cell wall, cytoplasm, etc.
- a structure of the cell wall of bacteria gram (+) and Gram (-)
https://www.e-biotechnologia.pl/Artykuly/Budowa-bakterii
https://szkolnictwo.pl/test,4,3794,15,Bakterie-pierwsze_organizmy_na_Ziemi-Bakterie_gramujemne

- Gram staining rules (staining mechanism) 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
Bacteria are picked up by students from various everyday objects - such as telephone, purse, keys, etc.
Bacteria collected from the surface of these objects can be grown in petri dishes, if possible, in incubators (but a radiator will suffice). After the agar has grown out of the bacteria, you can calculate the area occupied by the developing colonies using Software ImageJ.



Activity 4

A task is to demonstrate the enormous variety of forms and shapes of bacterial cells. The instruction for students is:
Build your 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.

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,

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lists pathogenic bacteria,
Lists the symptoms characteristic of such diseases as: tuberculosis, diphtheria, tetanus, gonorrhea syphilis and salmonellosis.

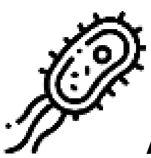
In terms of skills
Student:
compares the symptoms of various bacterial diseases,
determines the difference in the treatment of bacterial and viral infections,
argues the selected diagnosis of bacterial disease.

In terms of attitudes
Student:
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

RECOMMENDED ACTIVITY: 4

THE COURSE OF THE LESSON:



Activity 1

Analysis of patient cards
A patient (one of the students) comes to the doctor who knows what symptoms he has. The other students from the group fill in the patient's card by asking questions and trying to determine what is wrong with the patient (what disease he has).
A group of students of doctors - orders diagnostic tests.
In the second round, students who play the role of patients receive the test results and pass them on to the doctors. The student playing the role of the patient answers questions about the effects of diagnostic tests only if the doctors have ordered them.
Finally, they get feedback and compare their patient record with the student playing the patient.
- case report, role-playing of patients and diagnosticians - the patient can answer doctors' questions and present evident symptoms plus test results.
Diseases include tuberculosis, tetanus, borreliosis, salmonellosis, syphilis, and gonorrhea. (avaliable in Evaluation task and Educational materials file)

Activity 2
The students present what enabled them to diagnose the student's "disease" and the key symptoms of the disease.
Students create posters/infographics on the prevention of these diseases.

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 101006468.

Activity 3
Taboo game
Game rules:
Do not use any part of the password (or synonyms) that must be guessed.
You cannot use a plural or abbreviation for the password on the card.
You cannot gesticulate, but you can sing.
Most important: You cannot use the prohibited words that are on the card under the password.
List of game passwords:
Salmonella
Tuberculin test
Antibodies
ELISA test
Lyme disease
Serum

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.

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

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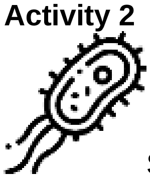
mind map
using microscopy
scientific modelling
brainstorming
discussion
RECOMMENDED ACTIVITIES: 2,5

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?
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 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
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?

Key information:
Life processes of bacteria
Bacteria live in the environment - so what coping strategies do they have when:
there is oxygen in the environment when there is no oxygen (e.g., in closed canned meat or yogurt) or when the amount is variable - aerobic respiration and anaerobic types of fermentation.
Additionally, it is also worth defining the conditions that determine the metabolic processes of bacteria. A teacher can discuss the results of experiments carried out earlier on lactate fermentation
. Considering the nutrition processes of heterotrophic bacteria, students might think about strategies in two situations. First situation is when there is little food available (this is almost always the case, and therefore bacteria have to use active feeding strategies and sometimes become spores). The other situation is when there is a lot of food (this is rarely the case, only on synthetic medium or perishable food). Even in the host's body, as long as the bacteria do not nest, they starve and are exposed to hunger stress.
Another strategy for managing food resources is independence - then these bacteria are autotrophic and carry out the process of photosynthesis or chemosynthesis.

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How do you meet your significant other when you are a bacterium? sexual processes and divisions (here, for example, G + bacteria secrete attractants, Gram-donor bacteria have fimbriae at the end of which there is a protein, and the receptor for this protein is in the cell of the second bacterium; the fimbria grabs this receptor, and the whole fimbria slowly begins to disintegrate, shortening the distance between partners when a threat/enemy appears? - bacterial stress; the source of bacterial stress can be:

- bacterial - bacterial interaction
- other organism interaction - bacterium or bacteriophage-bacterium interaction
- chemical wars - antibiotics - movie how antibiotics work

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).

Activity 3

Brainstorming your search for an answer to the question of what bacteria can do when an antibiotic appears

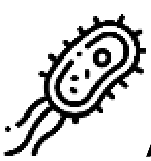
Responses that are close to the scientific explanations:
release something (a chemical) that will destroy the antibiotic,
seal the cell wall (so that the antibiotic does not get inside),
as the antibiotic gets in - make a pump - efflux, which will eject the antibiotic,
modification of the ingested antibiotic so that it is not so toxic,
modification of the target of the action of the antibiotic.
Finally, make a vote - ranking the solutions - which the students think is the best. Discuss the operation of these mechanisms. It is worth showing a movie about the principles of operation of the efflux pump.
efflux pump

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

Activity 4

The debate about whether antibiotic resistance is a problem in the modern world? Use of arguments.

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. Students can also check other conditions of the experiment to be controlled, such as

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the amount of nutrients in the pan, the amount of bacteria cells added. However, it is worthwhile to carry out these stages of controlling the conditions gradually. The program settings encourage students to repeat the experiment. At this point, it is helpful to ask students questions:
- why it is important to repeat the experiment
-why is it important to control all possible experimental conditions?
And questions that enable scientific modelling (i.e. explaining the phenomenon and making predictions, not only representing the phenomenon), e.g.
Is there a concentration of antibacterial substances that does not endanger the growth of bacteria?
Under what conditions even a small concentration of antibacterial substances will be a factor in eliminating the colonies of these organisms?
https://biomanbio.com/HTML5GamesandLabs/SciMethodGames/bacterialabpage.html

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,
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.

Methods and forms of work
visualization
discussion
analysis of the content of articles

RECOMMENDED ACTIVITY: 2

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 (e.g. smallest in the navel, greatest in the armpits on the skin), ask for sterile sites (there should be no sterile sites - in urine, blood, brain in general in tissues).
Discussion of the concepts of resident bacteria and transitional in the context of the drawn map (e.g., on the hands, they are mainly transitional) - discussion of the significance of the resident flora and the transitional flora.

Activity 2

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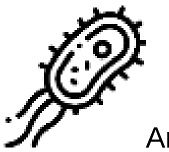 Analysis of articles on the microbiome
Problem question - are bacteria crucial to our mental and physical health - a second brain in the gut?
Problem question: is it correct to say that the gut microbiota rules the brain? Do we rule bacteria?
The student's task is to write down arguments enabling them 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.

Lesson 6. Bacteria - enemy or friend?

OBJECTIVES
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.

Methods and forms of work
discussion
exchange of ideas
concept map
content analysis

RECOMMENDED ACTIVITY: 1

THE COURSE OF THE LESSON:

Activity 1

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 101006468.


Discussion about:
What does enemy mean and friend mean in life, and what can it mean in biology?
The first recommended effect: - achieving fluidity and flexibility in terms and qualifying organisms to one of the groups, fluidity as a feature of living organisms, and, above all, the relationship between the examples of such variability - Queen bacteria E. coli - (symbiotic and enterotoxic strains)
The second recommended effect: is access to pathogenicity factors - what factors in bacteria make it an enemy and what makes it a friend (among these factors, e.g., toxicity, sticking - adhesion).

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.
Key concepts:
- the cycle of elements in nature
- production of food preparations
- sewage treatment plants.

Lesson 7. Bacteria in court

OBJECTIVES
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,
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:

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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.

One student is a judge - he is in charge of the trial
One student is an attorney
One student is the prosecutor
Several students are "witnesses."
The rest of the class is a "jury" or advisory body - making the decision and assisting the judge in the final decision.
Students prepare stories of witnesses and questions for witnesses.
The solicitor, prosecutor, and members can ask questions of the advisory body.
To begin with, the judge presents the trial plan - the order of testimony:
The first witness - a person suffering from salmonellosis
The second witness - a scientist - a microbiologist
The third witness is a sewage treatment plant worker
Field kitchen owner
A doctor discussing the physiological role of the presence of bacteria in the human body
Ecologist (complexity of the relationship between bacteria and other organisms)
A farmer who also owns a cheese farm
A historian*

*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 - Justinian's plague, the black death, the great Milan plague of 1629, typhus, smallpox, or premature deaths of rulers - e.g., Stefan Batory, Jan III Sobieski, Henry VIII Tudor) 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.

Finally, everyone ponders the following questions:
The judge announces that we have heard the prosecution and the defence. Now we will all try to convict or acquit. Here is a 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?

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Assessment methods
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 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 producedby bacteria**	**The influence of toxins on humanwater 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 producedby bacteria**	**The influence of toxins on humanwater management**
ETEC	**inside the gut/surface of the epithelial cells/outside of the epithelial cells**	**The disruption of the ion pumps ofthe 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 / protocooperationparasitism

Educational materials
The distribution of bacteria in your home - infographicPrinciples of creating a concept map - infographic
Ways of using E. coli by humans – infographic

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Lesson 7. Bacteria in court

Objectives
In terms of knowledgeStudent:
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 skillsStudent:
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,
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

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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 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.

<u>Indicative literature</u>

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2.6. Instituto Superior de Engenharia de Lisboa (ISEL)

AMENDMENTS

Amendments of the revised version of the educational scenario entitled: *"Respiratory Droplets and the Physics of Virus Transmission by Air"*

In terms of content, the scenario remained unchanged. The main changes made were to correspond to the numerous observations made by the teachers of the pilot schools during the implementation of the scenario. In this sense, this new version of the educational scenario is built so that teachers have a greater basis for being able to teach the subject in question, and the tools necessary for the scenario to be more dynamic were also created, and respect the time limit imposed for each lesson. With this, the number of learning resources was increased, and several learning scripts were created, both for teachers and for students, in order to enhance/instruct both groups in the activities that were intended for the scenario. The organization of the resources available for the scenario was also improved. One of the main aspects pointed out by the teachers during the implementation of the scenario was the fact that the resources provided are a little confusing and difficult to access. In this sense, the resources to be used in each lesson were organized, facilitating their access by teachers, as well as by students. The activities were also changed in order to make the scenario more practical and dynamic, meeting one of the teachers' concerns. Many mentioned that the previously proposed (research) activities involved some work monotony because they were very repetitive. The activities now proposed have been reorganized, being more dynamic, pulling more by the creative capacity of the students. With all these new elements, we now believe that the scenario allows for greater work flexibility during scenarios, gives teachers greater confidence to teach the topic, and is more engaging for students.

Amendments of the revised version of the educational scenario entitled: *"Sources of Energy and Impact on Public Health"*

In this scenario, the changes made were very similar to those conducted in scenario 1. Although this theme fits more into the programmatic content of the target students of this project. Teachers at pilot schools reported that working monotony was present in many classes, and that the resources made available were disorganized. As such, a reorganization of the elements available for this scenario was promoted, and the activities became more practical and dynamic. With this, we now believe that the timeout for each class will be met, allowing for greater work flexibility during scenarios, greater confidence for teachers to teach the topic, and more ability to captivate student interest.

Amendments of the revised version of the educational scenario entitled: *"Sound Pollution and Quality of Life"*

In this scenario, the changes made were very similar to those conducted in scenario 1. Although this theme fits more into the programmatic content of the target students of this project. Teachers at pilot schools reported that working monotony was present in many classes, and that the resources made available were disorganized. As such, a reorganization of the elements available for this scenario was promoted, and the activities became more practical and dynamic. With this, we now believe that the timeout for each class will be met, allowing for greater work flexibility during scenarios, greater confidence for teachers to teach the topic, and more ability to captivate student interest.

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2.6.1. Droplets and the physics of viruses transmission

Main partner responsible
ISEL

Context and relevance of the scenario for public health education
This scenario aims to prepare students and the school community to reduce the risk of airborne diseases. This work was primarily motivated by the latest Covid-19 pandemic crisis. Although it is still uncertain how the Sars-Cov-2 virus spreads in highly vaccinated populations, in the scientific community it is commonly accepted that the virus is airborne. In this sense, it is important to raise awareness among students and the school community on the topic, and to reflect on possible measures to be implemented, both individually and at school community level, that can mitigate the spread of respiratory droplets, to avoid the rapid proliferation of airborne diseases within the school community. The strategy to combat the Sars-Cov-2 pandemic worldwide was supported by the confinement of populations at home, the restriction of contacts between people, the promotion of the "two-meter social distancing" rule and 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 spread of respiratory particles, in different environments (e.g.: environments with different configurations, different number of occupants of the spaces, different number of tables and chairs, type of breathing regime (coughing, sneezing, normal breathing, gasping, among others), distance between regimes, , use/not use of mask) and thus, have a perception of the risk of transmission of diseases by respiratory route between individuals in each space. The learning scenario increases students' understanding of how airborne transmission of respiratory droplets works and how Science, Technology, Engineering, *Mathematics* (STEM) can contribute to anticipate, mitigate and solve public health threats, through the exploration of simulations obtained from a CFD tool.

Estimated duration
6 lessons of 40-45 minutes (lesson 1 - lesson 6)
6 sessions of 40-45 minutes for the 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 groups of four or five members to develop the school research project.
Use of a computer is required.
It is recommended that the room is already prepared before the students start working, i.e. before the lesson starts, the tables are previously arranged for group work, and the computers are operational.
It is necessary to carry out a preliminary survey of the extensions required in the room to support the connection of all computers.

Prerequisite knowledge and skills
Computer use and basic knowledge of Microsoft Office software will be required.
Knowledge of English (basic level) required.

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Content Glossary

Air Flow - Refers to the amount of air moving through a given space. It can be created by natural phenomena (natural air impulsion, or natural ventilation), or it can be created artificially by mechanical ventilation (air conditioning system).

Respiratory Diseases - Any disease that is caused by a microorganism that is transmitted through the air. These organisms can be spread by sneezing, coughing, spraying liquids, spreading dust or any activity that results in the generation of aerosolized particles. Airborne microorganisms can also be spread via liquids.

Airborne Transmission - The nuclei of respiratory droplets remain in the air for long periods of time, having the opportunity to spread widely in a variety of settings, such as a ward, hospital, or operating room, where particles can be spread directly between patients, or indirectly through contact with contaminated medical devices. Household activities, such as sweeping, using dry cloths and mops, or shaking out bed linen, send particles into the air that may contain microorganisms.

Computational Fluid Mechanics (CFD)- It is the process of mathematically modeling a physical problem/phenomenon involving fluid flow, and solving it numerically using a computational tool. Computational fluid mechanics is based on the Navier-Stokes equations. These equations describe how characteristic parameters of fluid mechanics, such as the velocity, pressure, temperature and density of a fluid, are related.

Respiratory Droplet Nucleus- It is a type of particle involved in the spread of airborne infections. Droplet nuclei are tiny particles (1-10 µm in diameter), which represent the dry content of droplets. This fraction can be formed by evaporation of droplets that have been emitted in coughing or sneezing situations.

Droplet Transmission Process - Disease-causing bacteria and viruses are carried in the mouth, nose, throat and respiratory system. These elements can be spread through direct contact with droplets emitted by an infected person when coughing or sneezing, or through saliva or mucus present on hands that have not been properly disinfected.

Fluid Mechanics- Fluid mechanics refers to a subdiscipline of mechanics that deals with the flow of moving fluids. Other areas of study such as Aerodynamics and Hydrodynamics are involved in Fluid Mechanics. Fluid mechanics involves the calculation of various fluid parameters such as fluid flow velocity, pressure, density and temperature as a function of space and time.

Incompressible Fluids - A fluid whose density remains constant for isothermal pressure variations.

Natural Air Ventilation - This is a way of supplying conditioned air (tending to be fresh air) to a building/room, typically through wind speed or pressure differences between the outside and inside.

Navier-Stokes Equations - In Fluid Mechanics, it is a partial differential equation that describes the flow of incompressible fluids.

Respiratory droplets - A small watery droplet produced by exhalation, consisting of saliva, mucus and other matter derived from respiratory activity. Respiratory droplets are produced naturally in different breathing regimes, such as breathing at rest, coughing, sneezing, or talking.

Respiratory disease - A type of disease that affects the lungs and other parts of the respiratory system. Respiratory diseases can be caused by viruses, tobacco smoke, or by inhaling second-hand tobacco smoke, asbestos and other forms of air pollution. Respiratory diseases include asthma, chronic obstructive pulmonary disease (COPD), pulmonary fibrosis, pneumonia and lung cancer.

Thermodynamics - It is the field of science that relates phenomena of heat, work, temperature and energy. In general, thermodynamics studies 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 certain defined amount of

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mechanical work.
Ventilation system - It is a mechanical system that provides air conditioning, with certain characteristics, to a given space, depending on the air conditioning needs.
Viscosity - It is the resistance of a fluid (liquid or gas) to a change of state, or to movement.

Pedagogical glossary

Active learning. A teaching and learning approach that "engages students in the learning process through activities and/or discussion in class, rather than just hearing theoretical concepts from the expert. This type of learning emphasizes critical thinking and often involves group work".
Brainstorming. *Brainstorming* is an instructional technique with several variations, which can be carried out in groups or with the whole class. During *brainstorming*, all learners quickly express their ideas or concepts that they think are relevant to a given question or basic concept. Scrutiny of the ideas presented is not carried out during *brainstorming* where the aim of the activity is to produce several divergent ideas/viewpoints on the same topic.
Collaborative learning. Collaborative learning is a didactic model that involves a set of pedagogical techniques, during which learners cooperate and/or collaborate during the learning process, as opposed to using the traditional teaching methodology used in schools. Collaborative learning can improve learning outcomes, learners' level of interest and participation, as well as their collaboration and communication skills.
Debating technique. Verbal technique used to involve a group in a particular topic to be presented/debated. This technique consists in dividing the class into several groups where each one participates in the discussion of a general topic and in building a "general commitment" among all.
Teamwork. Deepens knowledge, develops research and problem-solving skills; develops participation/intervention, cooperation and creativity skills; develops teamwork attitudes, social skills and knowledge.
Quiz-based learning. Inquiry-based learning with the participation of learners in learning activities during which they develop various scientific inquiry skills. Learners make use of these skills to answer scientific questions posed by the learners themselves or by the teacher, and through the treatment/analysis of experimental data collected by themselves or obtained through other sources. Some common research skills include building and using models, conducting experiments, collecting and organizing data, manipulating variables, drawing conclusions from data processing, and communicating about scientific issues.
Project-based learning. Project-based learning is a pedagogical model of active learning. It has several strands, during which learners work in groups to develop projects, which often refer to problems or situations with conditions close to those we encounter in real life. Project-based learning includes the phases of initiation, development and presentation of the project.
Sources: https://www.britannica.com/;Public Health Agency of Canada; EuroHealthNet; National Library of Medicine

Indicative Literature

Houghton, E. L. & Carpenter, P. W. (2003). *Aerodynamics for Engineering Students*, Fifth Edition. Butterworth-Heinemann. pp 52-89.
Moukalled, F., Mangini, L. & Darwish, M. (2016). *The Finite Volume Method in Computational Fluid Dynamics, An Advanced Introduction with OpenFOAM and Matlab*. Springer Publishing. pp 3-8.

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Versteeg, H. K. & Malalasekera, W. (2007). *An Introduction to Computational Fluid Dynamics, The Finite Volume Method,* Second Edition. Pearson Education. pp 1-4, 9-16.

<u>Competences / Learning Goals</u>

Key competencies

STEM/ personal, social, citizenship

Knowledge

Physics concepts:

Air flow;
Ventilation system;
Fluid mechanics;

Concepts of epidemiology:

Transferability;
Sociability;
Infectiousness;
Spread of the epidemic;

Concepts of medical science:

Respiratory droplets;
Social Distancing;
PPE (Personal Protective Equipment);
Respiratory Diseases;

Knowledge - Outcome Assessment:

It explains, in generalized form, the process of spreading viruses by air.
Identifies factors that influence the spread of respiratory droplets.
Identifies sources of risk in the environment.
Identifies measures and proposes general actions to combat airborne diseases.
Understands how ventilation systems can help mitigate the spread of airborne viruses.

Skills (Capabilities/Competencies)

In general: curiosity, cooperation, critical thinking, self-awareness, citizenship, problem definition, problem solving, analysis and discussion of facts, argumentation, public speaking and presentation, participation in brainstorming, debate, hypothetical-deductive reasoning, inductive reasoning, problem-based learning, understanding scientific principles and models, planning and carrying out a research-based project, critical thinking, teamwork, analysis and understanding of computer simulations, understanding applications of mathematical models, risk assessment and decision making.

Specific:

Find, analyze and interpret scientific data, texts and dynamic graphical representations to understand the public health impact of airborne diseases.

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Understands the difference between facts and opinions, understands how to find doubtful information, assesses the credibility of health-related information based on various factors that influence the credibility of information.
Understands the relevance of scientific facts to explain phenomena related to public health and airborne diseases, and produces argumentation.
It assesses individual and community risks and patterns of risk and protective behavior.
Define appropriate strategies that reduce the risk of infection, both at individual and community level, of airborne diseases.
Understands the importance of using a computational tool in assessing and predicting risks of infection of airborne diseases, taking into account the configuration of spaces.

Competencies - Outcome Assessment:
Obtains, evaluates and communicates facts related to airborne virus transmission.
Can anticipate the consequences of certain risk behaviors (e.g. not putting your arm in front of your mouth when you are about to sneeze or cough).
Rejects risky behavior in the presence of others (e.g. not wearing masks in enclosed spaces when their use is mandatory or recommended).
Feels able to influence the adoption of prevention behaviors of other people (e.g. family, colleagues, friends).

Affective/Attitudes/Behavior
Adopts general risk perception attitudes.
Adopt attitudes to minimize the risk of airborne diseases (e.g. awareness to keep shared spaces well sanitized).
Promotes communication and debate on risk reduction measures, specifically public policies that impact on the health of the school community and the wider community.
Use computational tools to solve complex mathematical problems related to public health.

Affective, Attitudes and Behavior - Outcomes Assessment:
It believes that civic-minded and conscious behavior is key to preventing the disproportionate proliferation of airborne diseases in the school community and the community at large.
Believes that individual behavior has an influence on the incidence of airborne diseases.
You disapprove of risky behavior patterns in your living environment.
It believes that the use of computational tools can help in solving problems involving STEM areas related to public health.

Learning objectives and outcomes
Uses computational tools to construct tables, graphs and other data to aid understanding of the physical process behind droplet propagation.
Obtains, evaluates and communicates science-based data and information on airborne diseases.
Use facts to build arguments about airborne transmission of viruses.
Gives examples of factors that influence airborne virus transmission in the community.
It describes different approaches to protecting, developing and positively influencing public health.

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Assessment methods
Outcome assessment
Quantitative - paper questionnaire.
Qualitative - students' project.

Process evaluation - evaluation of the teaching-learning sequence - observation grid: target audience reach and extension; implementation of the scenario as planned; execution of the learning scenario as expected/organizational issues to be solved; duration of the teaching-learning sequence; number of people exposed; evaluation by level of involvement in the project - learners ("Was it fun to do the project?"/Do you think it would be fun to do the project again?")/"How do you think the project could be improved?").

Content
STEM content
Fluid Mechanics.
Computational Thermodynamic Calculus.
Computational Fluid Mechanics.
Navier-Stokes equations.
Equation of momentum.
Numerical Investigation on Respiratory Droplet Distribution in Closed Spaces.
The spread of diseases by air.

Non-STEM content
Adoption of a civic-minded lifestyle to avoid and mitigate risks.

Digital Learning Objects (LOs) and Digital Educational Resources (DERs)
Created specifically for the PAFSE project
Computational Fluid Dynamics (CFD) Tool (**OA1**)
Repository of simulation results obtained with the CFD tool. (images, videos) **(DER1)**
PowerPoint presentation of the essential concepts of the scenario **(DER2)**
PowerPoint learning guide for teachers with the introductory concepts (**DER3).**
PowerPoint presentation on how to construct and analyze a scientific document. (**DER4**)
Explanatory document on the application logic of CFD simulations. (**DER5**)
Learning guide for teachers with the sequence/explanation of the analysis of the videos of lesson 3 and the respective completion of the worksheet. (**DER6**)
Learning guide for students of the sequence of analysis of the videos of lesson 3 and the sequence of filling in the respective worksheet. (**DER7**)
PowerPoint presentation, exclusive for teachers, with the detailed explanation of the videos to be analyzed in lessons 3 and 4. (**DER8**)
Learning guide for teachers with the sequence/explanation of the analysis of the videos of lesson 4 and the respective completion of the worksheet. (**DER9**)
Learning guide for students of the sequence of analysis of the videos of lesson 4 and the sequence of filling in the respective worksheet. (**DER10**)
PowerPoint presentation on how to build a poster (**DER11**)
Worksheets (including a version with resolution for each worksheet) (**DER12**)

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Suggestive summative assessment sheet (**DER13**)

Resources mentioned above, available at the following link:
https://iselpt-my.sharepoint.com/personal/nuno_domingues_isel_pt/_layouts/15/onedrive.aspx?id=%2Fpersonal%2Fnuno%5Fdomingues%5Fisel%5Fpt%2FDocuments%2F2023%2005%20Revis%C3%A3o%20dos%20cen%C3%A1rios%20ap%C3%B3s%20implementa%C3%A7%C3%A3o&ct=1690219328648&or=OWA%2DNT&cid=40882c0e%2Da059%2D85ef%2D3567%2D21b63a5e95f2&ga=1

Educational resources drawn from other high quality sources/platforms

About the process of airborne transmission of viruses

https://engineering.purdue.edu/~yanchen/paper/2006-3.pdf(Page 1-4). (**DER13**)
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7196697/(Table II). (**DER14**)
https://aip.scitation.org/doi/pdf/10.1063/5.0063475(DER15)
https://www.healthline.com/health/disease-transmission#indirect-contact (**DER16**)
https://www.medicalnewstoday.com/articles/317632#common-airborne-diseases (DER17)
https://www.webmd.com/lung/what-are-airborne-diseases (DER18)

On the size and duration of the suspension of respiratory particles in the air

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 (DER19)

Results from CFD simulations on respiratory particle propagation

https://www.youtube.com/watch?v=aDLs3vbzZag **(DER20)**
https://reader.elsevier.com/(**DER21**)
https://re.public.polimi.it/ (DER22)
https://www.buffalo.edu/ccr/services/research-highlights.host.html/content/shared/www/ccr/research-highlights/simulations-of-indoor-space-with-the-sterispacetm-air- sterilization. **(DER23)**

About Respiratory Diseases

https://www.healthline.com/health/airborne-diseases **(DER24)**
https://www.medicoverhospitals.in/articles/air-borne-diseases (DER25)
https://aip.scitation.org/doi/pdf/10.1063/5.0063475 (DER30)
https://www.initial.com/pt/todos-os-sectores/higiene-em-centros-comercias (DER31)

On how to prevent the spread of respiratory diseases with the help of ventilation

https://www.daikinapplied.uk/news-center/preventing-the-spread-of-coronavirus-with-ventilation-systems/(DER26)

Information on what is behind the CFD tool

https://www.britannica.com/science/Navier-Stokes-equation (DER27)

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https://re.public.polimi.it/retrieve/handle/11311/930957/444623/Numerical%20and%20experimental%20analysis%20of%20airborne%20particles%20control%20in%20an%20operating%20theater_11311-930957_Romano.pdf (completion of articles only)**(DER28)**
https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=0fe1dae233f76168f0e0448172a28ca2d21cc952 (article summary only) (**DER29**)

Teaching-learning activities (lesson plan/learning process)
Target Discipline:
Physical chemistry lessons (Physics strand), science clubs.
9th grade (pupils +/- 15 years).
About 6 lessons of 40-45 minutes duration.
Physics teachers integrate other colleagues in the implementation of the scenario (e.g. ICT, Science, Mathematics, English teachers), as the implementation of the scenario aims to be interdisciplinary.

Topics of each lesson:
Class 1: Presentation of the scenario and its introductory concepts.
Lesson 2: Explore concepts of the physics of airborne virus transmission
Lesson 3: Analyze CFD simulations of an initial case study
Lesson 4: Analyzing CFD simulations of a more complex case study
Lesson 5: Presentation and discussion of the results obtained from the analysis of the simulations
Lesson 6: Conclusion of lesson 5 and discussion on the school research project

Lesson 1: Presentation of the scenario and its introductory concepts
The main objectives to achieve in this lesson, from the learner's perspective, are:

Can identify the main physical parameters that influence the spread of respiratory particles.
Understands how a CFD simulator can assist in the prediction, prevention and spread of airborne diseases.

Lesson summary 1:
In lesson 1, the project is introduced to the students and the essential concepts of Fluid Mechanics and Computational Fluid Dynamics (CFD) are explored in a simple way, as well as some of the potentialities of the CFD tool. Discussion on how to construct and analyze a scientific document.

Activity 1
At the beginning of the lesson, the teacher discusses with the pupils the objectives and the planning of the next lessons, mentioning how the PAFSE project will be implemented, and the school research project. The teacher explains the main objectives to be achieved with the implementation of the scenario:
Students study problems related to the spread of airborne respiratory particles and human infection in a given room and under predefined conditions.
Learners explore and explain the problem by understanding how airborne transmission of particles/viruses works.
Students search for scientific information about respiratory particulate runoff, research it in reliable sources, and share their ideas with the teacher and classmates.
Students explore a computational tool that simulates the flow of particles in closed spaces.

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Students understand the complexity of the process (airborne particle dissemination), but that with the support of a computational tool **[LO1]** the phenomena are easier to predict, characterize and analyze;
Learners understand that simulators are relevant computational tools for solving real-life problems.
Pupils have a general understanding of the principles of physics and the mathematical equations that explain the spreading of particles and the operation of a computational tool.
Students analyze and study results obtained from the computer simulations, explain the behavior of the particles inside the room and the differences observed between simulations.
Learners understand how particle flow develops in different environments and propose measures and recommendations to prevent or mitigate the spread of airborne particles in school and community spaces.
Based on the computer simulations and the entire teaching-learning process, proposals and recommendations for community health are developed by the students and presented to the community, at the open school event, in the form of a poster, constituting the creation of this element, the school research project.

Activity 2
To start the implementation of the scenario, the teacher uses the PowerPoint created for this lesson with the name "Introduction Scenario 1". (**RSP2**). In order for the teacher to understand what is intended to be transmitted to the students with this document, and the way it should be transmitted, the teacher uses the script with the name "Introduction PPT script". (**DER3**). The PPT consists of 6 slides and contains the fundamental introductory concepts to be conveyed to students about Computational Fluid Mechanics (CFD), and the physics of airborne virus transmission. The presentation of this document will be fundamental for students to establish a link between the scientific contents inherent to the scenario and the activities they will subsequently develop in the following classes.
As already mentioned, the PPT "Introduction Scenario 1" consists of 6 slides, where the explanation of the content of each slide is mentioned in the document "Introduction PPT Guide". In order for the lesson not to be only theoretical, but to involve the participation of the students, each slide starts with a question, to which the students answer and question the options of the other colleagues, thus generating a critical debate on the topic in question. The questions to be posed to students on each slide are as follows:
"What is Fluid Mechanics (FM)? What fluid properties are analyzed in FM?"
"What forces act on a breathing particle?"
"How to relate the properties and forces of a fluid?"
"Do we need to know how to solve the Navier-Stokes equations? How to analyze results from CFD simulations?"
"How to apply Computational Fluid Mechanics to a problem?"
"Let's Remember..."
The general answers to each question mentioned above, which can be analyzed in detail in the document "Introduction PPT Guide" (**DER3**), are as follows:

Answer Question 1: It is the area of Mechanical Engineering that studies, analyzes and interprets the movement of any fluid, in liquid (e.g. water, oil, etc.) or gaseous (e.g. air, polluting gases, etc.) state, in space and time. In Fluid Mechanics, the movement of a fluid is called fluid **flow.** The properties to be analyzed to interpret the flow of a fluid vary from problem to problem. For example, if the fluid was incompressible (e.g. water), the analysis of the density of this same fluid may be negligible, but as a rule, the properties that are most used to analyze the flow of a fluid are its temperature, pressure, density,

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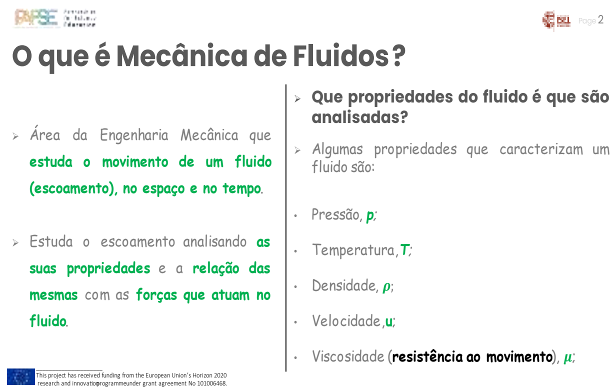
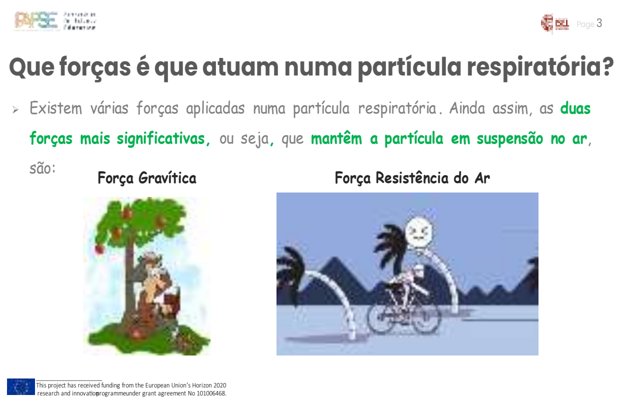
velocity, and viscosity, the latter being one of the most important, since it allows to analyze the degree / index of resistance to movement by a fluid. In the image illustrated below it is possible to analyze the slide in question.



Answer Question 2: In the PowerPoint this question is directed to the forces that act specifically on the breathing particles, which is the fluid that the students analyze in the scenario. In this sense, there are two forces that are concurrently applied to a breathing particle and that allow it to remain in suspension for some time, until it eventually settles on the floor, walls, people, is evaporated, or until it is subdivided into smaller particles. One is the gravitational force, which in the PowerPoint is represented with the famous image of the apple that fell on Isaac Newton's head, and the other force is the air resistance or *drag force* which is represented in the PPT with an image of a cyclist running against the wind. In the image illustrated below it is possible to analyze the slide in question.



Answer Question 3: The relationship between properties and forces of a fluid is established mathematically by means of the famous Navier-Stokes (N/S) equation. (**DER27**) This is a 2nd order partial differential equation that allows to characterize the 1D, 2D and 3D (in theory) motion (flow) of any fluid under normal circumstances. By simplifying the Navier-Stokes equation, we obtain Newton's famous 2nd law, the law of dynamics, F = ma. It is reinforced that the explanation of each term of the N/S equation is present in the document "Introduction PPT Guide". **Note: Nevertheless**, the explanation found in this script is not necessary to be transmitted to the students, as its content is not suitable for the students targeted by this project. This explanation only serves to empower teachers on this topic, so that they can teach this PowerPoint without difficulties. What is essential with this question/slide is that students understand later,

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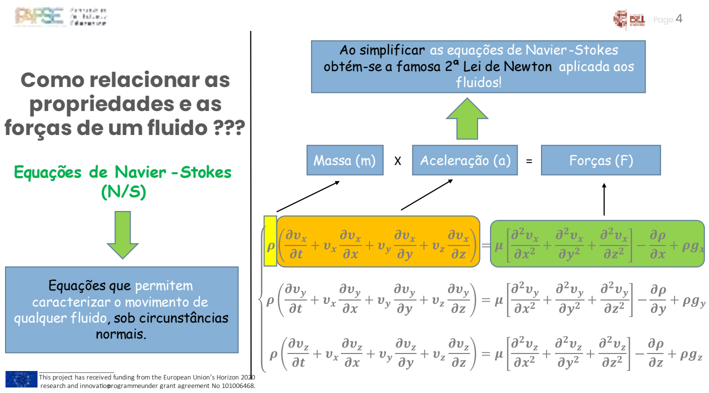
what is behind the CFD simulations they will analyze, and the scientific method inherent in creating a simulation of this content. In the image illustrated below it is possible to analyze the slide in question.



Answer Question 4: In the answer to this question the Computational Fluid Mechanics (CFD) tool [**AO1**] is presented. As mentioned, the Navier-Stokes equations are 2nd degree partial differential equations. The "simple" fact that they are already differential equations complicates their resolution, which in itself presents infinite solutions, and the fact that they are 2nd degree equations complicates their resolution even more. With technological advances, there is now a computational tool that allows solving these Navier-Stokes equations, from the simplest case to the most complex. The area that works with this computational tool is called Computational Fluid Mechanics, but it is commonly referred to as CFD (*Computational Fluid Dynamics*). In the slide corresponding to question 4 it is mentioned that, currently, the CFD tool is already applied in the most diverse areas of science, such as in the areas of medicine, biology, engineering (eg aerodynamics, and mechanics). Usually the results of solving the Navier-Stokes equations, and therefore of the simulations, can be presented in the form of graphs, images, tables, etc. In the slide corresponding to the answers to question 4, results of CFD simulations referring to aerodynamic resistance tests of the wing of an airplane and a formula 1 car are represented, as well as results of CFD simulations that were analyzed for the realization of this project, intending with these illustrations, to demonstrate to the students what can be obtained with CFD. It is reinforced that the detailed explanation of what is observed in each image is present in the "Introduction PPT Guide" (**DER3**). **Note:** It is essential to mention in this slide that the use of the CFD tool is of paramount importance because it allows its user to simulate an event even before it occurs, and with that draw the appropriate conclusions, something that students will do when analyzing the particle flow simulations for different breathing regimes, and in different room configurations. In the image below it is possible to analyze the slide in question.

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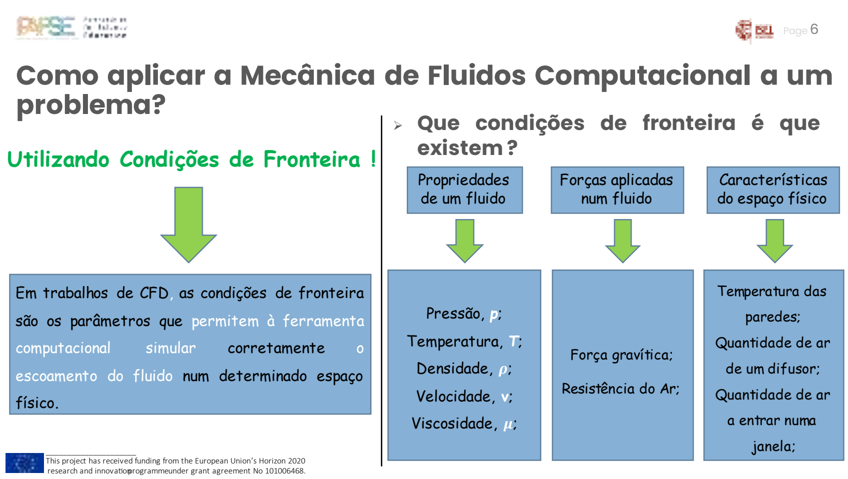
Answer Question 5: Initially, it is necessary to convey the notion that any CFD software will always solve the Navier-Stokes equations to produce a given simulation. Now, in order to simulate a given situation, it is necessary to enter into the CFD software 3 fundamental characteristics about that specific situation: the properties of the fluid in question and the forces acting on it, as well as the characteristics of the physical space to be simulated. Without the input of all these characteristics, the CFD software will never be able to effectively simulate the flow of a desired fluid in a specific situation. In Computational Fluid Mechanics, these characteristics are referred to as **boundary conditions**. The first two characteristics (properties and forces) have already been addressed. Regarding the characteristics of the physical space to be simulated, these parameters concern, for example, the dimensions of the space where the flow is simulated, the properties of the ventilation system (e.g. air flow rate of the diffusers, size of the equipment), temperature of the walls and of the skin surfaces of the occupants of the room, the degree of opening of a window or door, or the temperature and/or the velocity of the outside air entering the room. The slide in question can be analyzed in the image below.



Point 6: Point 6 is in itself an interactive activity that learners develop. On the slide for this point, learners have a summary table with a series of spaces that they fill in with the correct answers, depending on what has been taught. Learners are divided into groups and answer the blanks. The general idea to convey with this slide is to give the following overview of what was discussed in the PowerPoint presentation:

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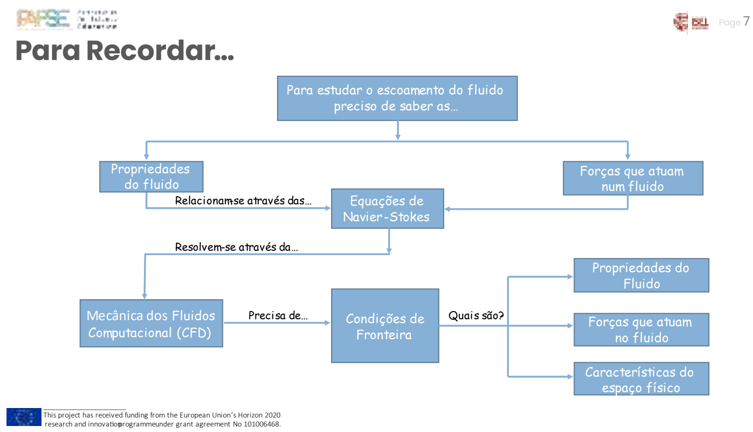
To study fluid flow, you need to know the properties of the fluid and the forces acting on it.
Both parameters (properties and forces) of a fluid are related through the Navier-Stokes equations.
To solve the complex Navier-Stokes equations we have at our disposal a tool, Computational Fluid Dynamics (CFD).
To use this tool I need to enter the boundary conditions into the CFD software.
The boundary conditions are the properties of the fluid, the forces acting on it, and the characteristics of the physical space.
In the image below you can see the summary table in question, as well as the spaces that the pupils will have to fill in.



Final Note Activity 2: As described throughout the description of activity 2, teachers have at their disposal both the PowerPoint "Introduction Scenario 1" and the respective explanatory script "Introduction PPT script". In addition to these elements, teachers also have access to a document entitled "CFD Usage Logic" (**DER5**) which contains precisely, the *modus operandi of* handling the CFD tool so that, in the first instance, it helps to train teachers to teach on the topic in question, and, out of possible interest, can serve as an initial basis for a deeper knowledge in this scientific area. Each document mentioned above is also accompanied, at its end, by additional literature on Fluid Mechanics and Computational Fluid Mechanics (CFD).

Activity 3

Activity 3 is started at the end of lesson 1, and if necessary, completed in lesson 2. In this activity, and because it is important to provide *feedback to* students on how to proceed to search for credible information to carry out a research paper. A new PowerPoint presentation entitled "Tutorial: How to Write and Read a Scientific Document" was prepared, which the teacher uses to explain to the students how a scientific document is constructed and how a scientific document is analyzed. (**DER4**) To make the activity more interactive with the students. The first 2 slides have a question in advance, which the students answer before the content of the slide is shown. The questions are "What is the importance of reading a scientific document?", and "How to read a scientific document". In this way, a debate is generated among the students, allowing the development of their critical and argumentative thinking. Fundamentally, the **RSP4** is divided into 2 parts: the first part exposes the sequence of how to read/analyze a scientific document, as well as how to remove the information that is useful to us, and the second part aims to convey to students, step-by-step, how they can build a scientific document from scratch. The document also presents

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the different conventional typologies to compose the subchapter of bibliographic references (e.g. *Vancouver, IEEE),* containing examples of how to mention a bibliographic reference in each of the typologies mentioned. The aim of this activity is, on the one hand, to provide students with the necessary skills for the next class where they will have to research scientific information, and on the other hand, to demonstrate how one of the most important stages of research work in STEM areas is usually carried out: with research, collection and processing of data that will later be useful in a work that is being conducted.

Learning objects to be used in class 1:
Computational Fluid Dynamics (CFD) Tool (**OA1**)
Repository of simulation results obtained with the CFD tool. (images, videos) **(DER1)**
PowerPoint presentation of the essential concepts of the scenario **(DER2)**
PowerPoint learning guide for teachers with the introductory concepts (**DER3).**
PowerPoint presentation on how to construct and analyze a scientific document. (**DER4**)
Explanatory document on the application logic of CFD simulations. (**DER5**)
https://www.britannica.com/science/Navier-Stokes-equation(DER27).

<u>Lesson 2: Explore concepts of the physics of airborne virus transmission</u>
<u>The main objectives to be achieved in this lesson, from the learner's perspective, are:</u>

Recognizes and characterizes the general physical process of spreading respiratory particles.
Identify factors that influence the spread of droplets.
Identify diseases that spread by air.

Lesson Summary 2:
Practical activity on the physical process of airborne particle propagation.

Activity 1
In case the teacher did not complete activity 3 in lesson 1, he/she can use the beginning of lesson 2 to conclude the presentation on how to read and construct a scientific document. Next, the teacher proposes to the class an activity that aims to analyze, explore and deepen the knowledge that the students have acquired in lesson 1 regarding the physical process of particle transmission. For this purpose, the teacher divides the class into groups of 4/5 students and distributes to the students the worksheet proposed for this lesson (**DER12).** The worksheet is composed of 3 questions, where in the first one students have to carry out an autonomous research on the physical process of respiratory particle transmission, in the second one they have an interactive crossword puzzle to fill in with concepts taught in class 1, and in the third question they have a multiple choice where they will need to proceed again to a research activity to correctly answer the question related to the dimension of a respiratory particle. The worksheet to be distributed to the students/groups in this lesson is represented by the images illustrated below.

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Cenário 1: "Gotículas Respiratórias e a Física da Transmissão de Doenças Respiratórias"

Unidade Curricular: ______________
Docente:______________

Ficha de Trabalho Nº 1: Física da transmissão da partícula respiratória

Nome:______________________________ Nº:__________

Data:_____/_____/______

1. Tendo em conta o que já sabes sobre o tema, e fazendo uma pesquisa, responde às seguintes perguntas:

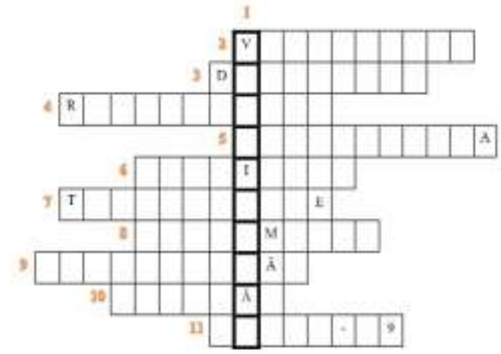
1.1 Têm alguma ideia de como é que as partículas se propagam pelo ar? (**Nota:** podes aceder aos links que se encontram mais abaixo na secção "Para saber mais…", onde, pela palavra-chave, consegues encontrar informação para esta pergunta).

Projeto PAFSE: Cenário 1: "Gotículas Respiratórias e a Física da Transmissão de Doenças Respiratórias"

1

1.2 Preenche o seguinte jogo de palavras-cruzadas relacionado com o tema da aula.

1 . Sistema mecânico de circulação de ar.
2 . Propriedade de um fluido.
3 . Propriedade de um fluido.
4 . Força que atua numa partícula respiratória.
5 . Propriedade de um fluido.
6 . Força que atua numa partícula respiratória.
7. Doença que se propaga por via aérea.
8. Nome para movimento de um fluido.
9. Doença que se propaga por via aérea.
10 . Propriedade de um fluido.
11 . Doença que se propaga por via aérea.



1.3 Qual o intervalo de dimensões de uma partícula respiratória ? Assinala a opção correta. (**Nota:** utiliza os links da secção "Para saber mais…" para responderes à pergunta corretamente).

a) 1 a 10 µm.
b) 1 a 2000 µm (micrómetro).
c) 50 a 500 µm.
d) 100 a 1500 µm.

Projeto PAFSE: Cenário 1: "Gotículas Respiratórias e a Física da Transmissão de Doenças Respiratórias"

2

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Para saber mais…

Se quiseres explorar mais sobre o tema desta aula, tens disponível na "Tabela Palavras-Chave" um conjunto de links com informações adicionais relacionados com cada palavra-chave. Para acederes a essas informações, é só carregares nos links que se encontram na secção "Referências" correspondente ao número que viste na tabela.

Tabela Palavras – Chave

Palavras-Chave	Nº de Referência
Dimensão Partículas Respiratórias	[1]
Propagação de Partículas Respiratórias	[2]
Doenças que se transmitem pelo ar	[3] [4]

Referências

[1] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7196697/

[2] https://aip.scitation.org/doi/pdf/10.1063/5.0063475

[3] Airborne Diseases: Types, Prevention, and More (healthline.com)

[4] AirBorne Diseases | Medicover Hospitals

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Each worksheet of this scenario contains a version with solution, which is available in the link present in the subchapter of the digital learning objects. Regarding the constitution of this worksheet, it is possible to observe at the end of it the section "To know more...", which has a table where several keywords are identified with a number of the corresponding bibliographic reference.

Below the table are links to each of the references mentioned in the table. In these links, learners will be able to find the answers to questions 1 and 3 by simply selecting the correct keyword. Briefly, the answer that students should give to research questions 1 and 3, was the following:

Answer Question 1: As seen in Lesson 1, particles propagate and stay suspended in air due to the presence of external forces applied on the particle, namely the force of gravity and the force of air resistance, and due to the thermodynamic conditions of the space in which the particles were emitted (pressure, temperature/humidity and air velocity). Smaller particles tend to stay suspended in the air longer, traveling greater distances, and larger particles tend to settle earlier on the surfaces around them.

Answer Question 3: The size of the breathing particle depends on the breathing regime, as noted in Table II of **RSD14**, where these values can range from 1 to 2000 μm.

In the research activity, the teacher reinforces what has already been worked on in the PowerPoint presentation of the end of lesson 1/beginning of lesson 2 (**RSP4**), i.e. the fact that learners always have to check the following criteria before taking the information they have obtained in the research as valid:

The source and author of the information.

The date it was published, as the older a document is, the higher the risk of the information being out of date.

Additionally, the teacher encourages students to search for information in reliable databases (e.g. WHO database) and scientific articles, so that these two conditions are guaranteed.

During the activity, the teacher circulates around the classroom and checks if the students are having any difficulties in searching and processing information. If this happens, the teacher should reinforce the idea that students can go to the "To find out more..." section to get the answers to the research questions and can structure the supporting information on the topic from the following resources:

https://engineering.purdue.edu/~yanchen/paper/2006-3.pdf(Page 1-4). **(DER13)**

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7196697/(Table II). **(DER14)**

https://aip.scitation.org/doi/pdf/10.1063/5.0063475 (Article introduction only) **(DER15)**

https://www.healthline.com/health/airborne-diseases (Respiratory Disease Information) (RCD16)

https://www.medicoverhospitals.in/articles/air-borne-diseases(Respiratory Disease Information) (RCD17)

In the crossword puzzle activity, students are asked to identify 4 properties of a fluid mentioned in lesson 1: density, velocity, temperature, pressure. 2 external forces that are applied on a breathing particle, also mentioned in lesson 1: gravity, air resistance. 3 diseases that spread by air: tuberculosis, covid-19, cold. The scientific name used in fluid mechanics for movement of a fluid mentioned in lesson 1: flow. The key word of the game: ventilation.

At the end of the session, the teacher informs the pupils that the answers to the worksheet should be kept for further discussion in lesson 5 which will be for the pupils to present and discuss the answers they have given on the various worksheets they have completed in the previous lessons.

Important Final Note: In order to create the dynamism of the activity, and to respect the proposed time limit for the class (40-45 minutes), it is imperative that some logistical issues are already previously ensured before starting the class, such as:

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It is absolutely necessary that learners have access to the internet in order to access the links provided in the sheet, either through computers or through their smartphones.
It is important that before starting the lesson, the classroom is already arranged for group work, i.e. before entering the classroom the tables should already be arranged for group work.
If computers are used, a prior assessment of the need for extension cords should be made, as it is possible that the classroom has few electrical outlets.

Learning objects to be used in class 2:
PowerPoint presentation on how to construct and analyze a scientific document. (**DER4**)
Explanatory document on the application logic of CFD simulations. (**DER5**)
Worksheets (including a version with resolution for each worksheet) (**DER12**)
https://engineering.purdue.edu/~yanchen/paper/2006-3.pdf(Page 1-4). **(DER13)**
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7196697/(Table II). **(DER14)**
https://aip.scitation.org/doi/pdf/10.1063/5.0063475 (Article introduction only)(DER15)
https://www.healthline.com/health/airborne-diseases (Respiratory Disease Information) (RCD16)
https://www.medicoverhospitals.in/articles/air-borne-diseases(Respiratory Disease Information) (RCD17)

Lesson 3: Analyze CFD simulations of an initial case study
The main objectives to achieve in this lesson, from the learner's perspective, are:

It uses concepts from physics to explain the process of spreading respiratory particles in enclosed spaces.
Can find, analyze and interpret scientific data, texts and dynamic graphical representations to understand the impact of airborne diseases on public health.
Understands the relevance of scientific facts to explain phenomena related to health and respiratory diseases, and produces argumentation.
Use computational tools to improve your knowledge of the process of spreading viruses through the air.
Understands how ventilation systems can assist in preventing/mitigating the spread of respiratory diseases.

Lesson Summary 3:
Analysis of CFD simulations of an initial case study. Students will, through the analysis of simulation results, in the form of videos, observe the influence that the variation of the parameters that characterize the process of propagation of respiratory particles has on their behavior for different breathing regimes. Afterwards, students will carry out the practical activity to consolidate the knowledge acquired during the class.
Organization of class 3 materials
As mentioned in the summary, this lesson is divided into 2 parts: a first one in which students analyze a series of CFD simulations results by watching 3D videos of the propagation of respiratory particles emitted in 3 different breathing regimes (**DER1**): situation in which a person speaks, sneezes or coughs. In the second phase, students fill in the proposed worksheet (**RWD12**) to consolidate the observations of the videos. In addition to the aforementioned videos, the following materials are available for this lesson:
Images of different perspectives of the room at the end of each CFD simulation, to assist learners in interpreting the results of their simulations. (**DER1**)
A learning guide for teachers of the sequence and explanation of how the videos should be analyzed by

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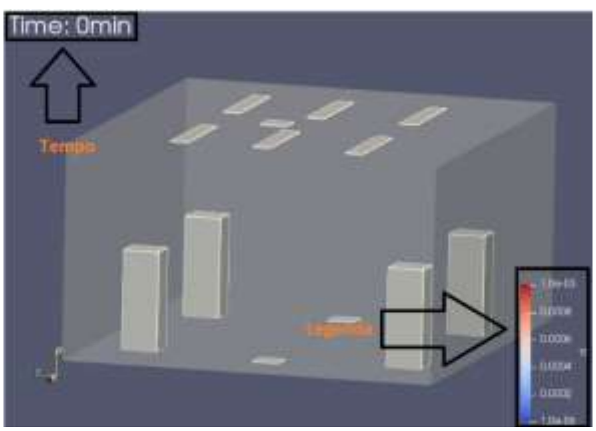
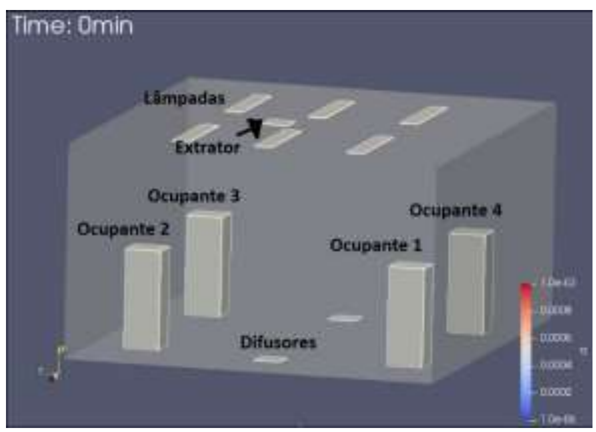
the students and how they should fill in the worksheet (**RSP6**).
A learning script for students to be read before and during lesson 3, with the sequence that should be followed to analyze the videos and to fill in the worksheet. (**RSP7**).
A PowerPoint, exclusive for teachers, with a detailed step-by-step explanation of the configuration of the videos, and the phenomena observed in each video. (**DER8**).

As mentioned above, the explanation of what is observed in each video and the sequence of analysis and completion of the form by the students is described in detail in **DER8** (document entitled "Video Analysis Guide Lessons 3 and 4") and **DER6** (document entitled "Lesson 3 Teacher Guide") respectively (resources available in the subchapter digital learning objects). The plan to be followed in this lesson is briefly described below.

Activity 1
At the beginning of the lesson students are divided into groups of 4/5 students and analyze videos of CFD simulations of 3 different breathing regimes: situation in which a person speaks, sneezes or coughs. For each situation mentioned, the room has a ventilation system, so to establish a point of comparison, students will also analyze a situation where a person speaks, but the room has no ventilation system. Only occupant 1 emitted particles (see right image below). To analyze the results of the CFD simulations, the students will have at their disposal 2 types of videos: one in which only the 1st minute of the simulation is seen, and a second in which the entire simulation is observed. Each simulation was conducted for a total time of 60 minutes. The simulation time can be seen in the top left corner of each video. In the lower corner there is a color legend representing, in meters, the size of each particle emitted by the emitting occupant. The scale goes from $1 \cdot 10^{-6}$ m (blue color) to $1 \cdot 10^{-3}$ m (orange color). The room where each breathing regime was simulated is the same for the cases of lesson 3, except for the absence of a ventilation system in the case where the person speaks without a ventilation system. In the images illustrated below it is possible to observe the legend/identification of each of the elements present in the room.





As mentioned above, learners will also be provided with a set of images from different perspectives of the room at the end of each simulation (**RSP1**) to help them interpret the phenomena observed in the videos. In the images below, some of these images are exemplified for the case in which occupant 1 was talking.

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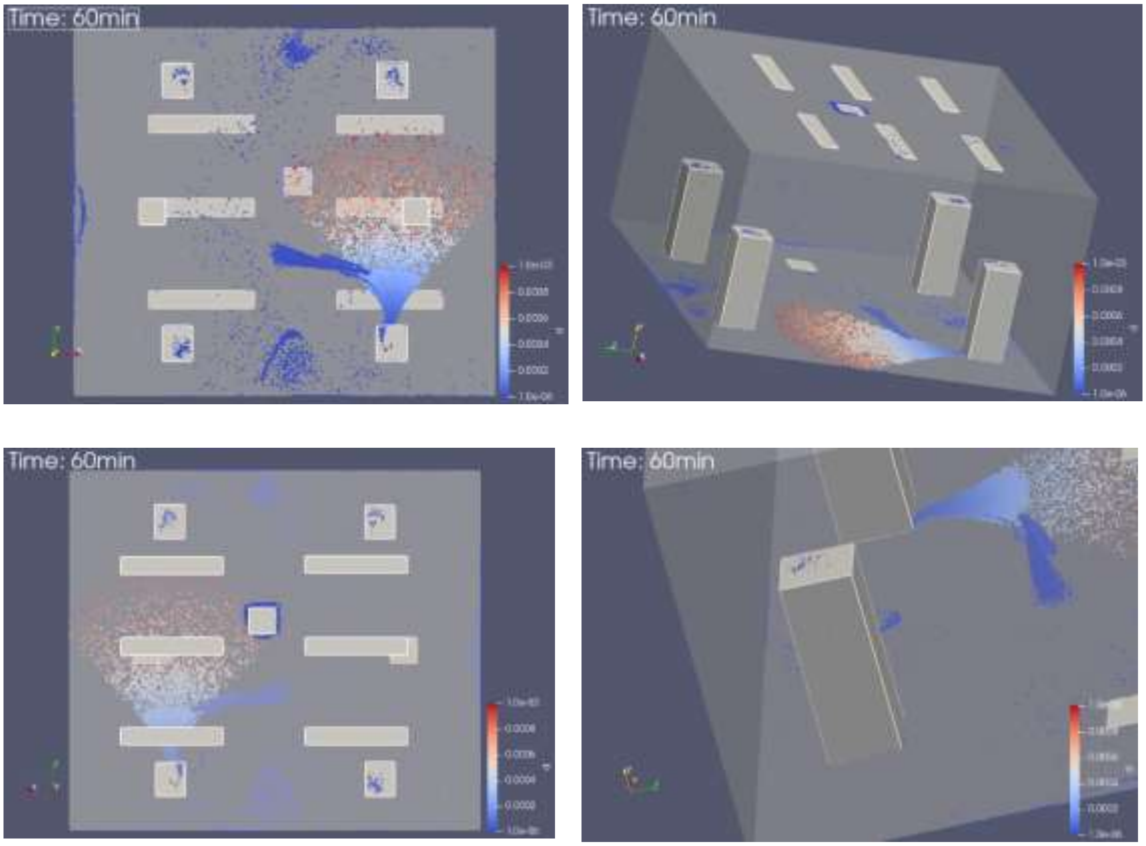

The students will also be provided with 2 more pictures of the draft lines in the room, for the situation with and without ventilation system. The explanation of what draft lines are can be found in **DER3.** The sequence to be followed by the pupils to analyze the videos is as follows:

Learners analyze the 1st minute videos for the 4 situations, where preferably the situation with and without ventilation should be analyzed next, i.e. if they analyze the video where the occupant speaks with ventilation, it is advisable that the video to analyze immediately after is the one where occupant 1 speaks without ventilation;

Afterwards, learners analyze the 4 videos of the total simulation;

If necessary, learners view the images from different perspectives of the room at the end of each simulation;

It is of utmost **importance that students have with them (or printed, or on their devices), the image with the identification of the elements of the room (**present in **RSP6** and **RSP7**), so that, when analyzing the videos, they can clearly identify each element inside the room. In order for this analysis activity to be conducted efficiently, the teacher asks the students in advance (e.g. in the lesson before the analysis of the videos) to analyze the learning guide "study method lesson 3" (**RSP7**) so that when the students arrive in lesson 3, they already have an idea of what they will have to do in this activity. To reinforce this last point, it is also suggested that at the beginning of the lesson the teacher tells the students how the sequence of analysis of the videos should be done, also mentioning what types of video there are, the existence of the images, etc.

Activity 2

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In activity 2 each group answers the practical worksheet developed for this lesson. (**DER12**) The worksheet is composed of 5 questions about the videos that the students have watched, also making a link to the knowledge acquired in lessons 1 and 2.
As mentioned, each worksheet has a version with solution that can be consulted in the link provided in the subchapter of the digital learning objects. The 5 questions that students answer are the following:

"It indicates whether there were any occupants who were more affected than others, in each simulation."
" Explain why there were differences between the CFD simulations where occupant 1 spoke with and without ventilation."
" Taking into account the elements that are part of room 3 (occupants and ventilation system), how did each of these elements influence the flow of particles?"
" Explain why the larger particles (oranges) were deposited more in the room, and the smaller particles (blues) were removed in greater numbers"
"Was the risk of infection for occupants always the same for the 3 breathing regimes? Explain why ."

After answering the questions, the students also prepare a short scientific report summarizing the main results observed in the videos of the CFD simulations. This activity can be carried out as a T.P.C. of class 3 in case the class time is insufficient to fulfill the activity. With the elaboration of this report, the students will be consolidating the knowledge acquired in the last classes, and at the same time they will be implementing the scientific method for problem solving since they will be going through the phase of analyzing results (observation of the videos and images of the CFD simulations), producing conclusions (answers to the questions of the worksheets and elaboration of the scientific report), later carrying out the scientific debate / argumentation in class 5 when they expose their conclusions. The worksheet to be distributed to the students/groups can be seen in the images below.

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Cenário 1: "Gotículas Respiratórias e a Física da Transmissão de Doenças Respiratórias"

Unidade Curricular: ____________

Docente: ____________

Ficha de Trabalho Nº 3: Caso de Estado Inicial

Nome ____________ Nº ____________

Data ___/___/______

1. Tendo em conta o que observaste nas imagens e vídeos relativos aos resultados das simulações CFD da aula 3, e o que aprendeste nas aulas 1 e 2, responde às seguintes perguntas.

1.1. Observando as imagens abaixo que representam a perspetiva na diagonal das simulações CFD para os regimes de respiração de falar e espirrar, indica se houve algum ocupante que foi mais afetado que os outros, em cada simulação.

Simulação Falar | Simulação Espirrar

1.2. Explica o porquê das diferenças observadas entre as simulações CFD em que o ocupante 1 falava com e sem ventilação. Para te ajudar a responder, podes utilizar as imagens abaixo que representam cada um das situações.

Simulação Falar | Simulação Falar Sem Ventilação

1.3. Como viste na aula 1, a força de resistência do ar influencia o escoamento das partículas respiratórias. Tendo em conta os elementos que fazem parte da sala 3 (ocupantes e sistema de ventilação), como é que cada um destes elementos influenciou o escoamento das partículas? Para te ajudar a responder estão representadas abaixo 3 imagens da sala ao longo do tempo (aos 5, 15 e 60 minutos), para a simulação de falar.

1.4. Na aula 1 verificaste que havia vários parâmetros que influenciavam o escoamento das partículas respiratórias, como a temperatura, a pressão ou a densidade. Com base nesse fator, explica a razão pela qual as partículas de maior dimensão (laranjas) ficaram mais depositadas na sala, e as partículas de menor dimensão (azuis) foram removidas em maior número.

1.5. O risco de infeção para os ocupantes, foi sempre o mesmo para os 3 regimes de respiração? Explica porquê.

2. Agora, tendo em conta o que observaste nos vídeo da aula 3 e as respostas que deste às perguntas do ponto 1, elabora um pequeno resumo descrevendo o que observaste nas simulações, destacando os principais aspetos.

Briefly, the answers that students should give to the questions on the sheet are as follows:

Answer to question 1.1: To assist in answering this question, students already have two images representing the end of the talking and sneezing simulations. What should be identified is that no humans were substantially affected, as few particles directly hit occupants 2, 3 and 4, as seen in the images represented on the sheet. Additionally, in the simulation of talking, talking without ventilation, sneezing and coughing, from the diagonal perspective images, and detailed of the occupants, we can conclude that occupants 2,3 and 4 were affected equally.

Answer to question 1.2: In this question students also have 2 representative images of each of the situations (end of the simulations where occupant 1 speaks with and without ventilation). Comparing the simulations with and without ventilation system it is observed that there is a higher number of particles suspended in the air (and remaining in the room) in the case without ventilation, since here there is no

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mechanism to remove the particles from the room. Thus, the case without ventilation poses a greater risk of infection to the occupants than the case without ventilation.

Answer to question 1.3: To help answer this question, students have represented the evolution of the speaking simulation over time with 3 images of the room (at 5, 15 and 60 minutes). They also have a small clue at the beginning of the question wording stating that in lesson 1 it was mentioned that the air resistance force influences the flow of breathing particles. What you want students to conclude is that in all simulated breathing regimes, the breathing particles follow the direction of the airflow, which forms a sort of "L" shape. The particles follow this direction due to their small size. On the other hand, what is also observed is that larger particles tend to deposit more easily, either on the occupants or on the walls. The geometries present in the room (in these cases, only the occupants), act as "barriers" to the normal trajectory of the particles, and as such, influence their flow.

Answer to question 1.4: Again in this question students have an initial clue when it is mentioned that in lesson 1 they found that there were several parameters that influenced the flow of the breathing particles. What we want students to answer is that the larger particles (orange) were deposited in greater numbers in the room compared to the smaller ones (blue) due to the fact that they were denser (heavier).

Answer to question 1.5: Regarding the risk of infection, it was found that in all breathing regimes, the risk of infection was quite low as direct contact between particles and occupants was almost non-existent. Even so, the risk of contagion by indirect means always exists (by contact of the occupants with the walls, for example), and the greater the number of particles inside the room, the greater the risk of infection, therefore, of all the situations analyzed, the case of talking will be the one that presents the greatest risk of infection for the occupants, since in this case a greater number of particles were emitted.

When writing the report, the main aspects that should be mentioned by the students are the following:

The particles tend to follow the airflow created by the ventilation system, describing an upward "L" trajectory towards the extractor, being successively removed from the room over time.
Occupant infection was almost residual for all 3 breathing regimes, due to the presence of the ventilation system.
The lower the number of particles emitted, the lower the risk of occupant infection.
In the situation without a ventilation system, particles were not removed, and the risk of occupant infection increased.
If necessary, as in the worksheet of lesson 2, students have available at the end of the worksheet the section "To know more...", a table where several keywords are identified with a number of the corresponding bibliographic reference. Below the table are links to each of the references mentioned in the table. In these links, learners will be able to find information that will help them to construct a more elaborate scientific abstract. The learning resources in these links are the following:
https://re.public.polimi.it/retrieve/handle/11311/930957/444623/Numerical%20and%20experimental%20analysis%20of%20airborne%20particles%20control%20in%20an%20operating%20theater_11311-930957_Romano.pdf (completion of articles only)**(DER28)**
https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=0fe1dae233f76168f0e0448172a28ca2d21cc952 (article summary only) (**DER29**)

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When the pupils are going to carry out the scientific report, the teacher reinforces what has already been worked on in the PowerPoint presentation of the end of lesson 1/beginning of lesson 2 (**RSP4**), i.e. the fact that the pupils always have to check the following criteria before taking the information they have obtained in the research as valid:

The source and author of the information.
The date it was published, as the older a document is, the higher the risk of the information being out of date.
Additionally, the teacher encourages students to search for information in reliable databases (e.g. WHO database) and scientific articles, so that these two conditions are guaranteed.

Important Final Note of Lesson 3: In order to create the dynamism of the activity, and to respect the time limit proposed for the lesson (40-45 minutes), it is imperative that some logistical issues are already previously ensured before starting the lesson, such as:
It is of utmost importance to ensure that before lesson 3 students already have access to the videos and detailed perspective images, either on computer or on their smartphones so that when they arrive at the lesson, they only need to open these elements.
It is important that learners have already read the learning guide "study method lesson 3" (RSP7) before lesson 3, so that they are already familiar with what they will encounter in the respective lesson.
It is absolutely necessary that learners have access to the internet in order to access the links provided in the sheet, either through computers or through their smartphones.
It is important that before starting the lesson, the classroom is already arranged for group work, i.e. before entering the classroom the tables should already be arranged for group work.
If computers are used, a prior assessment of the need for extension cords should be made, as it is possible that the classroom has few electrical outlets.

Learning objects to be used in class 3:
Computational Fluid Mechanics (CFD) Tool (**OA1**)
Repository of simulation results obtained with the CFD tool. (images, videos) **(DER1)**
(**DER1**)
A learning guide for teachers of the sequence and explanation of how the videos of lesson 3 should be analyzed by the students and how they should fill in the worksheet. (**DER6**).
A learning script, to be read by the students, before and during lesson 3, with the sequence that should be followed to analyze the videos and to fill in the worksheet. (**DER7**).
A PowerPoint, exclusive for teachers, with a detailed step-by-step explanation of the configuration of the videos, and the phenomena observed in each video. (**DER8**).
Worksheets (including a version with resolution for each worksheet) (**DER12**)

Lesson 4: Analyzing CFD simulations of more complex case studies

The main objectives to achieve in this lesson, from the learner's perspective, are:
It uses concepts from physics to explain the process of spreading respiratory particles in enclosed spaces.
Can find, analyze and interpret scientific data, texts and dynamic graphical representations to understand the impact of airborne diseases on public health.

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Understands the relevance of scientific facts to explain phenomena related to health and respiratory diseases, and produces argumentation.
Use computational tools to improve your knowledge of the process of spreading viruses through the air.
Understands how ventilation systems can assist in preventing/mitigating the spread of respiratory diseases.

Lesson Summary 4:
Analysis of CFD simulations of more complex case studies: rooms with different configurations. Students will, through the analysis of simulation results, in the form of videos, observe the influence that the variation of different room configurations influences the process of propagation of respiratory particles. Afterwards, students will carry out the practical activity to consolidate the knowledge acquired during the lesson.
Organization of materials for lesson 4
As mentioned in the summary, this lesson is divided into 2 parts: a first one in which students analyze a series of CFD simulations results by observing 3D videos of the propagation of respiratory particles emitted when occupant 1 was talking, in 3 rooms of different configurations (**DER1**): standard room, room with ventilation system fully installed on the ceiling and room with natural ventilation system. In the second phase, students complete the proposed worksheet (**DER12**) to consolidate the observations of the videos. In this lesson, the focus is on assessing the influence of different room configurations on the spread of respiratory particles. In addition to the already mentioned videos, the following materials are available for this lesson:
Images of different perspectives of the room at the end of each CFD simulation, to assist learners in interpreting the results of their simulations. (**DER1**)
A PowerPoint, exclusive for teachers, with a detailed step-by-step explanation of the configuration of the videos, and the phenomena observed in each video. (**DER8**).
A learning guide for teachers of the sequence and explanation of how the videos of lesson 4 should be analyzed by the students and how they should fill in the worksheet. (**DER9**).
A learning script for students to be read before and during lesson 4, with the sequence that should be followed to analyze the videos and to fill in the worksheet. (**DER10**).

As mentioned above, the explanation of what is observed in each video and the sequence of analysis and completion of the form by the students is described in detail in **DER8** (document entitled "Video Analysis Guide Lessons 3 and 4") and **DER9** (document entitled "Lesson 4 Teacher Guide") respectively (resources available in the subchapter digital learning objects). The plan to be followed in this lesson is briefly described below.

Activity 1
At the beginning of the lesson, students are divided into groups of 4/5 students and analyze videos of CFD simulations of the situation in which occupant 1 was talking, for 3 different room configurations: standard room, room with fully installed ceiling ventilation and room with natural ventilation. For each situation mentioned, students will have, as in class 3, 2 types of video to analyze: one in which only the 1st minute of the simulation is seen, and a second in which the entire simulation is observed. The simulation time and the color scale is also identical to the simulations of class 3. In the first instance, it is intended that students establish a relationship between the classroom of class 3 (less complex), with the standard room which is the same as the classroom of class 3, only with more geometric elements and humans have greater

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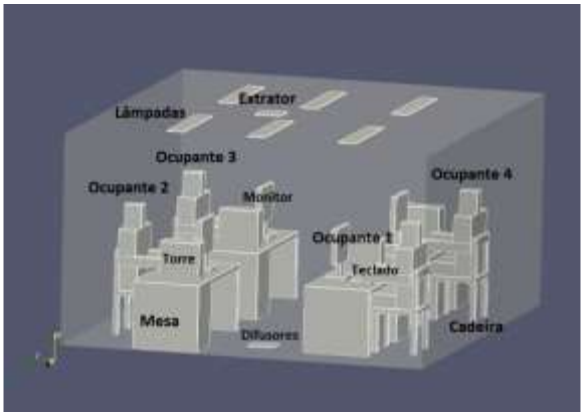
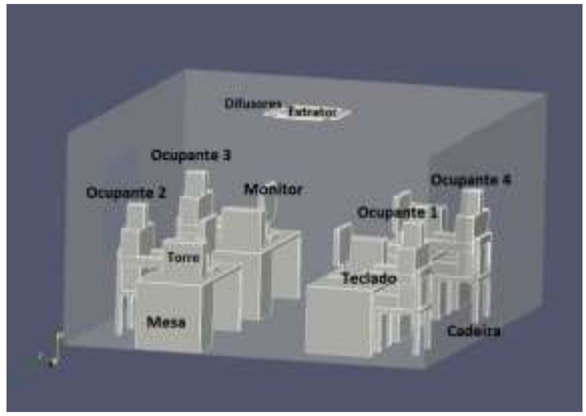
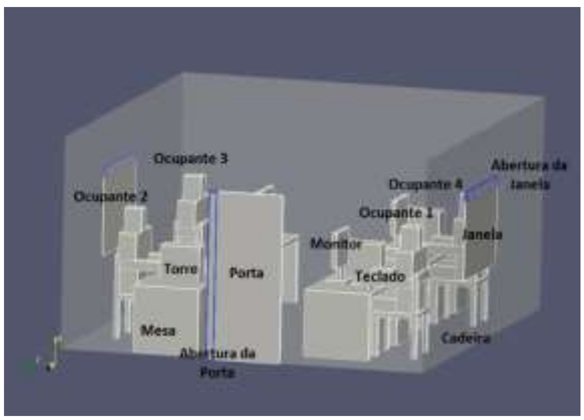
complexity. Subsequently, it is intended that students analyze and observe the differences in the propagation of respiratory particles when the rooms have different configurations, having to analyze the situation in which the room has a ventilation system fully installed in the ceiling, and with natural ventilation. The images below show the legend/identification of each room. The standard configuration is represented in the image on the left, the room with ceiling ventilation in the image on the right, and the room with natural ventilation represented in the image below.







As can be seen, compared to the room in lesson 3, the configurations of the rooms in lesson 4 present more elements (chairs, tables, towers, keyboards, etc.), and the occupants present more geometric complexity. As in class 3, students will also have at their disposal a set of images of different detailed views, for each room, at the end of the simulation. Students will also have access to images of the draught lines for each of the rooms. The explanation of what streamlines are can be found in **DER3,** and the explanation of the phenomena observed in each video can be found in **DER8.** The sequence to be followed by the students to analyze the videos is as follows:

Students analyze the 1st minute videos of the situation where occupant 1 spoke, for all 3 situations.
Afterwards, the students analyze the videos of the total simulation for the 3 situations.
If necessary, learners view the images from different perspectives of the room at the end of each simulation.

It is of utmost **importance that students have with them (either printed or on their devices), the image with the identification of the elements of the room, for configuration (**present in **RSD9** and **RSD10**) so that, when analyzing the videos, they can clearly identify each element inside the room. In order for this

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analysis activity to be conducted efficiently, the teacher asks students in advance (e.g. at the end of lesson 3) to review the learning guide "study method lesson 4" (**RSP10**) so that when students arrive in lesson 4, they already have an idea of what they will have to do in this activity. To reinforce this last point, it is also suggested that at the beginning of the lesson the teacher tells the students how the sequence of analysis of the videos should be done, also mentioning what types of video there are, the existence of the images, etc.

Activity 2

In activity 2 each group answers the practical worksheet developed for this lesson. (**DER12**) The worksheet is composed of 3 questions about the videos that the students have watched, also making a link to the knowledge acquired in lessons 1 and 2. The worksheet also contains a version with solution that can be consulted in the link provided in the subchapter of the digital learning objects. The 3 questions that students answer are the following:

Complete the scientific report on the differences observed between the simulations of lesson 3 and the standard case by filling in the blanks with the correct words.
Identify the main difference between the 3 room configurations and how this change influenced the propagation of the particles.
Identify which phenomenon marked in orange in the images of this question, is observed at the end of all simulations, what risks it may incur for public health and how we can solve this problem.

After answering the questions, the students also prepare a short scientific report summarizing the main results observed in the videos of the CFD simulations. This activity can be carried out as a T.P.C. of lesson 4 in case the time of the lesson is insufficient to fulfill the activity. With the elaboration of this report, the students will be consolidating the knowledge acquired in the last classes, and at the same time they will be implementing the scientific method for problem solving since they will be going through the phase of analyzing results (observation of the videos and images of the CFD simulations), producing conclusions (answers to the questions of the worksheets and elaboration of the scientific report), later carrying out the scientific debate / argumentation in class 5 when they expose their conclusions. The worksheet to be distributed to the students/groups can be seen in the images below.

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Briefly, the answers that pupils should give to the development questions on the sheet are as follows:

Answer to question 1.2: The major change that occurred between the 3 rooms was the use of a different ventilation system. In the standard room, the ventilation system of class 3 was maintained (diffusers on the floor and extractor on the ceiling), in the room with ceiling ventilation system, all the equipment (diffusers + extractor) was installed on the ceiling, and in the room with natural ventilation system, there was a current of air in the direction of the window openings to the door opening. Regarding the differences

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verified for each room, in terms of the trajectory traveled by the particles, it was verified that in the standard case, the particles tend to follow the air flow created by the ventilation system, describing an ascending trajectory in "L" in the direction of the extractor, being successively removed from the room over time, as was the case in class 3. In the case where the ventilation system was fully installed in the ceiling, the particles were found to be more dispersed inside the room. As a consequence, more particles remained in the room, and therefore the risk of indirect contagion in this case is higher than in the standard case. In the case of the room with natural ventilation system, the air current generated was in the direction from the windows to the door. As the door opening is small, there were fewer particles to be removed from the room compared to the previous situations (with mechanical ventilation system). As such, more particles remained in the room, and therefore, the risk of indirect contagion in this case is higher than the previous 2 cases.

Answer to question 1.3: In this question it should be noted that in all situations analyzed in rooms with mechanical ventilation system, there was an accumulation of particles in the extractor region at the end of the simulation. This phenomenon can constitute a potential risk of infection for the occupants of the room, since the particles accumulated there can return. As such, it is necessary to carry out periodic maintenance of this equipment, keeping it sanitized at all times.

When writing the report, the main aspects that should be mentioned by the students are the following:

The big difference observed between the case of class 3 and the standard case is related to the fact that in the standard case there are more geometric elements in the room, and as such, there are more "barriers" to the normal flow of particles, and the risk of infection by indirect route is higher.
Particles in both the standard case and the case with ventilation fully installed in the ceiling tend to follow the air flow created by the ventilation system, describing an upward "L" trajectory towards the extractor, being successively removed from the room over time.
In the natural ventilation system, the particles follow the air stream generated in the direction from the window opening to the door opening, where the particles are also removed over time.
Direct occupant infection was practically residual for all 3 room configurations due to the presence of the ventilation system (both mechanical and natural).
In the case with the ventilation system fully installed in the ceiling, it was found that the particles were more dispersed in the room, and as such the risk of indirect infection was higher in this case compared to the standard case.
In the case with natural ventilation system, as the door opening is small, and the air velocity entering the window is lower than the air velocity imposed by the mechanical ventilation system in the standard and full ceiling ventilation cases, there are fewer particles to be removed from the room, and as such, the risk of indirect infection was higher in this case compared to the previous 2 cases.
Over time, there has been an accumulation of particles in the extractor region, which may pose a risk to public health. To solve this problem, it is necessary to always carry out periodic maintenance of this equipment, keeping it sanitized.

If necessary, as in the worksheet of lesson 2, students have available at the end of the worksheet the section "To know more...", a table where several keywords are identified with a number of the corresponding bibliographic reference. Below the table are links to each of the references mentioned in

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the table. In these links, learners will be able to find information that will help them to construct a more elaborate scientific abstract. The learning resources in these links are the following:
https://re.public.polimi.it/retrieve/handle/11311/930957/444623/Numerical%20and%20experimental%20analysis%20of%20airborne%20particles%20control%20in%20an%20operating%20theater_11311-930957_Romano.pdf (completion of articles only)**(DER28)**
https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=0fe1dae233f76168f0e0448172a28ca2d21cc952 (article summary only) (**DER29**)
When the pupils are going to carry out the scientific report, the teacher reinforces what has already been worked on in the PowerPoint presentation of the end of lesson 1/beginning of lesson 2 (**RSP4**), i.e. the fact that the pupils always have to check the following criteria before taking the information they have obtained in the research as valid:

The source and author of the information.
The date it was published, as the older a document is, the higher the risk of the information being out of date.
Additionally, the teacher encourages students to search for information in reliable databases (e.g. WHO database) and scientific articles, so that these two conditions are guaranteed.

Important Final Note for Lesson 4: In order to create the dynamism of the activity, and to respect the proposed time limit for the lesson (40-45 minutes), it is imperative that some logistical issues are already ensured before starting the lesson, such as:
It is of utmost importance to ensure that before lesson 4 students already have access to the videos and detailed perspective images, either on computer or on their smartphones so that when they arrive at the lesson, they only need to open these elements.
It is important that learners have already read the learning guide "study method lesson 4" (RSP10) before lesson 4, so that they are already familiar with what they will find in the respective lesson.
It is absolutely necessary that learners have access to the internet in order to access the links provided in the sheet, either through computers or through their smartphones.
It is important that before starting the lesson, the classroom is already arranged for group work, i.e. before entering the classroom the tables should already be arranged for group work.
If computers are used, a prior assessment of the need for extension cords should be made, as it is possible that the classroom has few electrical outlets.

Complementary Activity
In order to reinforce students' knowledge, as a complementary activity to be developed outside the class, it is proposed that students also analyze the simulations of sneezing and coughing breathing regimes for standard cases, with ventilation system fully installed on the roof, and with natural ventilation system. The analysis of these simulations can help to compose the scientific report.

Learning objects to be used in class 4:
Computational Fluid Dynamics (CFD) Tool (**OA1**)
Repository of simulation results obtained with the CFD tool. (images, videos) **(DER1)**
A PowerPoint, exclusive for teachers, with a detailed step-by-step explanation of the configuration of the videos, and the phenomena observed in each video. (**DER8**).

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A learning guide for teachers of the sequence and explanation of how the videos of lesson 4 should be analyzed by the students and how they should fill in the worksheet. (**DER9**).
A learning script, to be read by the students, before and during lesson 4, with the sequence that should be followed to analyze the videos and to fill in the worksheet. (**DER10**).
Worksheets (including a version with resolution for each worksheet) (**DER12**)

Lesson 5: Presentation and discussion of the results obtained from the analysis of the simulations
The main objectives to achieve in this lesson, from the learner's perspective, are:

Use facts to build arguments about airborne transmission of viruses.
Evaluates and communicates science-based data and information on airborne diseases.
Can understand the relevance of scientific facts to explain phenomena related to public health and airborne diseases, and produce argumentation.

Lesson Summary 5:
Presentation of the resolution of the worksheets from lessons 2, 3 and 4, including the scientific reports prepared in lessons 3 and 4. Organization of a debate where students, based on the evidence they have verified in the analysis of the simulations, and on what they have studied in class 1, should propose measures to combat the spread of airborne diseases.

Activity 1
At the beginning of this lesson, each group presents their answers to the worksheets from lessons 2, 3 and 4. A time limit is set per group, and it is compulsory for each member of each group to speak at least once. While one group is presenting, the teacher asks the other groups to note down the main differences between the answers they gave and the ones the presenting group produced. This contrast of ideas will be a starting point for the discussion that will take place subsequently.

Activity 2
In this activity, a debate is generated in the class, in which, in the first instance, the different points of view among students are discussed, regarding the answers to the worksheets, and in a second moment, it is intended that students debate and produce conclusions about the main risk factors associated with the spread of airborne diseases, and what measures, general and individual, students would apply to mitigate the spread of such diseases. To address the first topic of the debate, the teacher can pose a series of questions to the class, which the students will have to answer, arguing with the answers they gave to the worksheets, in the production of the scientific reports of lessons 3 and 4, and in what they learned in lesson 1. Such questions could be:

"How do particles stay suspended in the air?"
"What factors influence the propagation of particles?"
"In which situation, class 3 or 4, were the occupants more exposed to particles? And why?"
"What configuration of classroom 4 do you think can help reduce the risk of infection from airborne diseases? Why?"
"Is the risk of infection for a person who talks, sneezes, or coughs always the same?"

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These and more questions, related to what the students answered in the worksheets, can be raised by the teacher in order to get the students to discuss what they observed in the videos and what they learned in lesson 1.

In the 2nd part of the debate, the teacher again lists a series of questions, which the students answer based on the worksheets, the scientific reports and what they have learned in lesson 1. To address this topic of the debate, the questions can be:

"What do you think was the main factor that allowed more particles to be removed from the room in the standard situation compared to the situation with natural ventilation?"
"What airborne diseases do you know?"
"What individual measures do you suggest to mitigate the risk of infection by airborne diseases? And at the school community level?"
"Do you think it is important to raise awareness in the community about this topic? And why?"

These and more questions, related to what the students have answered on the worksheets, can be raised by the teacher in order to get the students to discuss what they have observed in the videos and what they have learned in lesson 1. In order for the debate to be conducted effectively, the teacher should discuss the rules of the debate and ensure that they are followed:

The main focus of the debate:
The main focus of the debate is to use scientific argumentation to discuss the different points of view on what the groups answered in the worksheets, and on what general measures the students would select to apply, either in the community or at individual level to mitigate the risk of airborne disease spread.

The structure of the debate:
To carry out the debate the teacher divides the students into groups (4-5 students) and each group is given time to communicate a set of proposals on "How can we mitigate the risk of airborne transmission of the virus by influencing individual behavior?". The other groups should prepare counter-arguments to the proposals presented by their colleagues.

The rules of the debate:
Each member of each group must speak at least once, and the order and content of the speech is discussed in advance by the group members. After each group presents its measures, the other groups present their counter-arguments. The group that has just presented is then given time to rebut these counter-arguments. The presentation of the counter-arguments to the proposals made by colleagues should be made by only 1 member of each group, indicated by the teams. If the other groups agree with the arguments of the group that has just presented, they must present at least one suggestion or recommendation to the measures that have been mentioned by the group that has just presented.

Evaluation of the debate:
The evaluation of the debate is at the discretion of the teacher, but must involve the following criteria:
The group that submitted the best proposals.

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The group that best defended its point of view.
The group that best refuted the arguments of the other groups.

To facilitate the students' thinking and organization of ideas, they will be provided by the teacher with a worksheet (**RWD12**), where they should indicate the main risk factors they have identified, as well as the general measures to be applied to mitigate the spread of the virus by air. An example of the worksheet to be distributed to students/groups can be seen in the images below.


Unidade Curricular: ____________
Docente: ____________
Ficha de Trabalho Nº 6: Fatores de Risco Associados a Doenças Respiratórias

Quadro 1: Fatores de Risco Associados a Doenças Respiratórias e Medidas de Prevenção a Aplicar

Principais Fatores de Risco	Medidas Gerais a Aplicar


Quadro 2: Argumentos que Justificam as Opções Tomadas

Argumentos que Justificam as Opções Tomadas

If necessary, as in the worksheet of lesson 2, students have available at the end of the worksheet the section "To know more...", a table where several keywords are identified with a number of the corresponding bibliographic reference. Below the table are links to each of the references mentioned in the table. In these links, students can find information to help them fill in the more elaborate tables of this lesson's worksheet. The learning resources in these links are the following:

https://www.healthline.com/health/airborne-diseases **(DER24)**
https://www.medicoverhospitals.in/articles/air-borne-diseases (DER25)
https://www.daikinapplied.uk/news-center/preventing-the-spread-of-coronavirus-with-ventilation-systems/
(DER26)
https://aip.scitation.org/doi/pdf/10.1063/5.0063475 (DER30)
https://www.initial.com/pt/todos-os-sectores/higiene-em-centros-comercias (DER31)

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Learning objects to be used in class 5:
Repository of simulation results obtained with the CFD tool. (images, videos) **(DER1)**
Worksheets (including a version with resolution for each worksheet) (**DER12**)
https://www.healthline.com/health/airborne-diseases **(DER24)**
https://www.medicoverhospitals.in/articles/air-borne-diseases (DER25)
https://www.daikinapplied.uk/news-center/preventing-the-spread-of-coronavirus-with-ventilation-systems/ **(DER26)**
https://aip.scitation.org/doi/pdf/10.1063/5.0063475 (DER30)
https://www.initial.com/pt/todos-os-sectores/higiene-em-centros-comercias (DER31)

Lesson 6: Conclusion of lesson 5 and discussion on the school research project
The main objectives to achieve in this lesson, from the learner's perspective, are:

Identify the general factors that influence the spread of respiratory particles.
Identifies risk factors in various environments.
Identifies measures and proposes general actions to combat airborne diseases.

Summary of Lesson 6:
In lesson 6, students conclude the discussion on general measures to be applied to mitigate the spread of airborne diseases. The topic of the school research project is discussed.

Activity 1
Due to time constraints, lesson 5 may not be completed in the time allotted for the lesson, so activity 1 of lesson 6 will only be the conclusion of lesson 5.

Activity 2
In the second activity of lesson 6 the teacher uses **RSP11,** with the name "School Project, how to make a poster" to present the school research project to the class. Each group is challenged to construct a poster **(RSP6)** containing images, text, infographics, graphical representations, with the conclusions drawn from the analysis of the case studies. Students are encouraged to revisit the scientific articles they have consulted in the research process, to explain the results of the simulations and, based on this information, to elaborate their proposals. The best format for the presentation of the project results is discussed and the notes made by the groups throughout the implementation of the scenario (measurements, justifications, filling in the sheets, scientific reports, among others) are consulted during the realization of the project. This work developed by the students will later be presented at the open school event, as well as at the event organized by ISEL for the purpose of presenting the PAFSE project to its academic community. The **RSP11** is a PowerPoint that contains some examples of successful posters, as well as the main guidelines to follow to create a good poster. This document also contains an explanation of the overall objectives of the school research project, as well as a tutorial that students can follow to set up a PowerPoint slide in the dimensions for which the poster will need to be created.

Complementary activity
To conclude the implementation of the project, the teacher also has at his/her disposal a summative evaluation sheet **(RSP13)** that summarizes/consolidates the knowledge acquired throughout scenario 1.

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The teacher can use this document as an evaluation element of the project if he/she wishes. This sheet, like all the worksheets **(DER12),** contains a resolution. It is reinforced that both elements are available in the link mentioned in the subchapter of the learning objects. An example of the worksheet to be distributed to students/groups can be seen in the images below.

Cenário 1: "Gotículas Respiratórias e a Física da Transmissão de Doenças Respiratórias"

Unidade Curricular: ____________

Docente: ____________

Ficha de Avaliação Sumativa

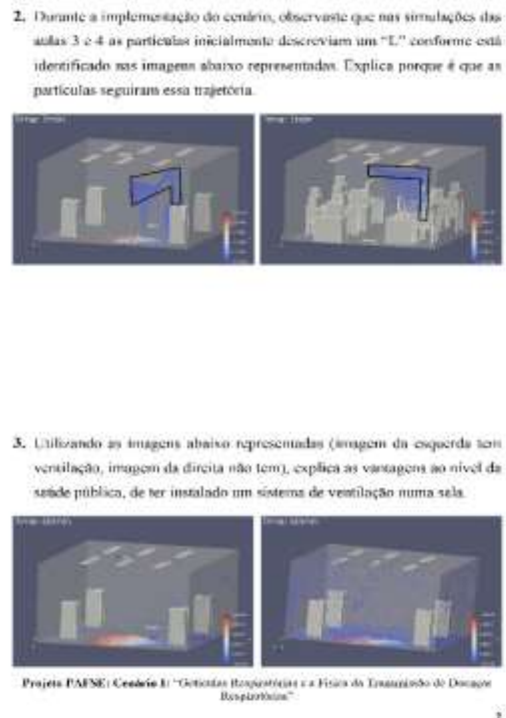
Nome: ______________________ Nº: ________

Data: ___/___/____ Classificação: ________

1. Tendo em conta os vídeos que analisaste ao longo da implementação do cenário, identifica no espaço em branco os elementos que estão circundados a laranja e a preto nas imagens abaixo representadas.

Projeto PAFSE: Cenário 1: "Gotículas Respiratórias e a Física da Transmissão de Doenças Respiratórias"

1



2. Durante a implementação do cenário, observaste que nas simulações das aulas 3 e 4 as partículas inicialmente descreviam um "L" conforme está identificado nas imagens abaixo representadas. Explica porque é que as partículas seguiram essa trajetória.

3. Utilizando as imagens abaixo representadas (imagem da esquerda tem ventilação, imagem da direita não tem), explica as vantagens ao nível da saúde pública, de ter instalado um sistema de ventilação numa sala.

Projeto PAFSE: Cenário 1: "Gotículas Respiratórias e a Física da Transmissão de Doenças Respiratórias"

2

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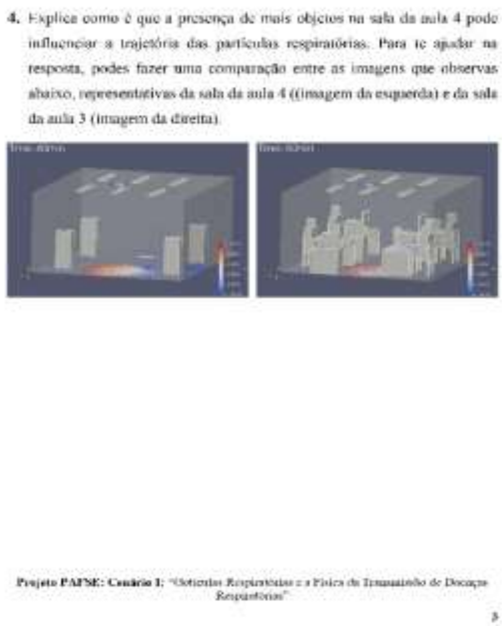
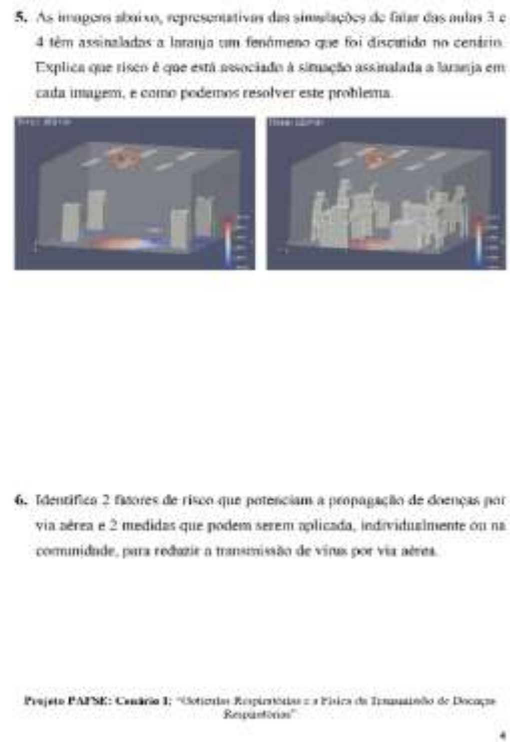


4. Explica como é que a presença de mais objetos na sala da aula 4 pode influenciar a trajetória das partículas respiratórias. Para te ajudar na resposta, podes fazer uma comparação entre as imagens que observas abaixo, representativas da sala da aula 4 ((imagem da esquerda) e da sala da aula 3 (imagem da direita).

Projeto PAFSE: Cenário I: "Gotículas Respiratórias e a Física da Transmissão de Doenças Respiratórias"

3



5. As imagens abaixo, representativas das simulações de falar das aulas 3 e 4 têm assinaladas a laranja um fenómeno que foi discutido no cenário. Explica que risco é que está associado à situação assinalada a laranja em cada imagem, e como podemos resolver este problema.

6. Identifica 2 fatores de risco que potenciam a propagação de doenças por via aérea e 2 medidas que podem serem aplicada, individualmente ou na comunidade, para reduzir a transmissão de vírus por via aérea.

Projeto PAFSE: Cenário I: "Gotículas Respiratórias e a Física da Transmissão de Doenças Respiratórias"

4

Learning objects to be used in class 6:
PowerPoint presentation on how to build a poster (**DER11**)
Worksheets (including a version with resolution for each worksheet) (**DER12**)
Suggestive summative assessment sheet (**DER13**)

<u>Supplementary learning resources and educational activities</u>

Invite STEM organizations.
Share simulation results with other schools in a repository platform (Visible but not editable).
Reflect on the analysis of simulations carried out by other schools.
Improve existing simulations and explore new ones.
Interact with professionals.
Disseminate the knowledge acquired to parents' associations and civil organizations.

<u>School Research Project</u>

Topics
Understands the process of Transmission of Respiratory Diseases.
Can list Respiratory Diseases
Can interpret results from a Computational Fluid Dynamics (CFD) tool.
Understands how a ventilation system can assist in mitigating the spread of airborne diseases.
Improves perception of public health issues.

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Research, analyze and communicate scientific information.
Develops responsible citizenship.

Research management, design and administration
Challenge: to explore the simulator, build their own simulations and report their results.

Development process (summary):
Based on the knowledge acquired in lessons 1-6, students will go to the laboratory of the mechanical engineering department of ISEL and interact with the computational tool. They will be able to build the spaces to be simulated, change the environmental conditions, observe the differences between each environment, and describe the results of the simulations through a short report. The teacher then proposes successive discussions on the reports produced in the form of "research seminars" to be held at school or in the science club. Students, parents, the school community and local stakeholders participate in the event and learn how the rapid spread of airborne diseases such as COVID-19 or other acute respiratory diseases such as influenza is influenced by individual behavior and environmental factors. They will also gain knowledge on strategies to be implemented to minimize the above phenomena, and how these measures can influence the spread of airborne diseases in various environments (e.g. home, school, workplace, public space). Students will visit the facilities of a fire department allowing them to see the personal protective health and safety equipment of first responders, the equipment and instruments in rescue and patient transport vehicles and understand the functioning of the integrated emergency medical system and know the procedures for assessing and monitoring victims.

Objectives of the teaching-learning process:
Students will be able to:
Develop critical thinking (e.g. analyze, organize, discuss and share information about simulation results).
Develop digital skills (e.g. find, review and use different online resources to develop the scenario activities).
Understand how a Computational Fluid Mechanics (CFD) tool is operated and its relevance to address public health threats.
Use concepts from physics to explain the process of spreading respiratory droplets in enclosed spaces.
Understand various factors that influence the spread of respiratory droplets.
Understand how a ventilation system can assist in mitigating the spread of airborne diseases.
Develop the ability to construct different types of arguments and counter-arguments to make decisions about social-scientific issues.
Develop the ability to debate socio-scientific issues.
Influence community perceptions and knowledge about airborne virus transmission.
Developing responsible citizenship and health literacy.

Teaching-learning process in relation to the school research project (summary):
Collecting facts (data, articles, photos)
Evaluation of facts based on criteria and selection of relevant, credible and non-biased information.
Evaluation of results from CFD simulations.
Design reports regarding CFD simulation results.
Development of criteria for evaluating arguments.
Preparation of a schedule of tasks for the open school event.

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Creation of a poster/PowerPoint presentation related to the measures to be taken to prevent/mitigate the spread of acute respiratory diseases for presentation at the open school event.

Organization of the open school event:

Each project result (simulations and report) is presented by the students in a community setting (e.g. exhibition center, municipality, garden, museum, science fair).

Learners will communicate the selected measures using STEM-based reasoning. Learners call for everyone to take action to improve the health of the community, providing a broad understanding that preventing the spread of a disease is everyone's responsibility, not just the health ministry or health care providers.

Stakeholders also gain knowledge regarding strategies to implement to minimize the above phenomena, and how these measures can influence the spread of airborne diseases in various environments (e.g. home, school, workplace, public space).

Target audience for recommendations

Other schools using the repository platform.
Social NGOs.
Policymakers.
General public.
Social Communication.
Families.
Friends.
Prospective students.

Public Debate and Recommendations (based on the survey results)

Presentation of the simulations report by the students in a community setting, and dissemination of factual recommendations via the media, community and mainstream.

Interaction between schools informing the school how their report (on the repository platform) improved the other school's project and study.

Networking between schools with a similar environment.

Discussion and feedback.

Produce a revised and improved report based on the reports produced by the other schools.

Make recommendations for public spaces.

Disseminate the final report and recommendations on the school website and inform key stakeholders in the local community (public transport companies, shopping centers, hospitals, among others).

2.6.2. Energy sources, and public health impact

Main partner responsible

ISEL

<u>Context and relevance of the scenario for public health education</u>

Air pollution is a global problem with effects on public health. 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, among others, are supported by considerable facts and arguments. The

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energy supply system is a major contributor to air pollution, which annually causes more than 7 million deaths worldwide, with more than 4 million deaths due to indoor (household) air pollution and more than 3.5 million due to outdoor (environmental) air pollution. Given the nature of planet Earth as an energy-dependent system, the educational setting supports physics teachers in organizing the classroom debate on the energy transition to more carbon-neutral environments. The learning experience prepares young people for a heightened awareness about energy sources and the importance of renewable energy to ensure the sustainability of the planet as a viable ecosystem. The impact of the consumption of different energy sources will be discussed, with a focus on the topic of energy rationalization, and its economic and environmental impacts. With this scenario, teachers will be raising awareness about the implications that energy choices have on problems such as air pollution, the planet and public health.

Estimated duration

6 lessons of 40-45 minutes (lesson 1 - lesson 6).
6 sessions of 40-45 minutes for the 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 groups of four or five members to develop the school research project. The use of a computer is required.

Prerequisite knowledge and skills

Computer use and basic knowledge of Microsoft Office software will be required, as well as knowledge of English (basic level).

Content Glossary

Air pollution - This is the release of various polluting gases into the atmosphere, or which can be dispersed through the air, at rates which exceed the natural capacity of the environment to dissipate, dilute or absorb them. These substances can reach concentrations in the air that cause harm to public health.
Chemical reactions - A process in which one or more substances, the reactants, are converted into one or more different substances, the products. Substances are 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 changes in temperatures and weather patterns. These changes can be natural, such as variations in the solar cycle. The consequences of climate change today include, among others, intense droughts, water shortages, severe fires, rising sea levels, floods, polar ice melt, catastrophic storms and declining biodiversity.
Combustion - A chemical reaction between substances, usually including oxygen and usually accompanied by the generation of heat and light in the form of a flame.
Primary energy - It is a form of energy found in nature that has not yet undergone any conversion process of human origin. It can be energy contained in fuels available in nature (primary energy), or it can be other forms of energy. Primary energy can be renewable or non-renewable.
Principle of Conservation of Energy- Principle of physics according to which the energy of interacting bodies or particles within a closed system remains constant.
Energy transfer process- Energy transfer is the process by which energy is transported from one system to another, for example, through heat transfer, work or mass transfer. Thermal energy transfers occur in

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only three ways: by conduction, convection and/or radiation. When thermal energy is transferred between neighboring molecules that are in contact with each other, this heat transfer phenomenon is called conduction. Convection is the transfer of thermal energy occurring in a fluid. Radiation is the transfer of thermal energy through space by electromagnetic radiation.

Energy Transformation Process- Energy transformations are processes that convert energy of one type (e.g., kinetic energy, gravitational potential, chemical energy) into another form of energy. Any type of energy use must involve some type of energy transformation. For example, the transformation of oil, natural gas or hydropower into electrical energy.

Indoor air pollution - Refers to the chemical, biological and physical contamination of indoor air. It can result in adverse health effects. In developing countries, the main source of indoor air pollution is smoke from biomass burning which contains particulate matter (5PM), nitrogen dioxide (NO2), sulphur dioxide (SO2), carbon monoxide (Ca), formaldehyde and polycyclic aromatic hydrocarbons (PAHs).

Outdoor air pollution - This is often referred to as ambient air. Common sources of outdoor air pollution are emissions caused by combustion processes from motor vehicles, burning of solid fuels and industrial activities. Other sources of pollution include smoke from forest fires, wind-blown dust and biogenic emissions from vegetation (e.g. pollen).

Renewable energy - These are ways of generating energy from (theoretically) unlimited natural resources. These resources are available on a time scale thought to be infinite, and are replenished at a rate greater than they are consumed. Renewable energies are also often referred to as 'green energies' or 'clean energies'. Still, this does not mean that these energies cannot be harmful to the environment and that they have zero impact. However, this type of energy has a low environmental impact compared to fossil fuels (Non-Renewable Energy).

Sustainable Energy Management - Combines management skills with an understanding of the responsible management of energy resources and the development of sustainable energy sources (e.g. wind, solar, biomass, hydro, geothermal, among others).

<u>Pedagogical glossary</u>

Active learning. A teaching and learning approach that "engages students in the learning process through activities and/or discussion in class, rather than just hearing theoretical concepts from the expert. This methodology emphasizes critical thinking and often involves group work".

Brainstorming. *Brainstorming* is an instructional technique with several variations, which can be conducted in groups or with the whole class. During *brainstorming*, all learners quickly express their ideas or concepts that they think are relevant to a given question or basic concept. Scrutiny of the ideas presented is not carried out during *brainstorming* where the aim of the activity is to produce several divergent ideas/points of view on the same topic.

Collaborative learning. Collaborative learning is a didactic model that involves a set of pedagogical techniques, during which learners cooperate and/or collaborate during the learning process, as opposed to using the traditional teaching methodology used in schools. Collaborative learning can improve learning outcomes, learners' level of interest and participation, as well as their collaboration and communication skills.

Debating technique. Verbal technique used to involve a group in a particular topic that will be presented/debated. This technique consists in dividing the class into several groups where each one participates in the discussion of a general topic and in building a "general commitment" among all.

Teamwork. Deepens knowledge, develops research and problem-solving skills; develops

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participation/intervention, cooperation and creativity skills; develops teamwork attitudes, social skills and knowledge.

Quiz-based learning. Inquiry-based learning with the participation of learners in learning activities during which they develop various scientific inquiry skills. Learners make use of these skills to answer scientific questions posed by the learners themselves or by the teacher, and through the treatment/analysis of experimental data collected by themselves or obtained through other sources. Some common research skills include building and using models, conducting experiments, collecting and organizing data, manipulating variables, drawing conclusions from data processing, and communicating about scientific issues.

Project-based learning. Project-based learning is a pedagogical model of active learning. It has several strands, during which learners work in groups to develop projects, which often refer to problems or situations with conditions close to those we encounter in real life. Project-based learning includes the phases of initiation, development and presentation of the project.

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/energyproduction-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 competencies

STEM/ personal, social

Knowledge

Physics concepts:
Energy production.
Energy transfer.
Conservation of energy.
Primary energy and fuels.
Renewable energy sources.
Non-renewable energy sources.

Environmental health concepts:
Environmental determinants of health.

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Pollution, climate change.
Indoor air pollution, sources.
Outdoor air pollution, sources.
Air pollution as a risk factor for non-communicable diseases (e.g. chronic lung disease).

Concepts of epidemiology and health economics:
1. Indicators of the impact of diseases related to loss of air quality (e.g. deaths caused by indoor and outdoor air pollution).

Social and global health concepts:
Sustainable Development Goals (SDG 3 in relation to 7, 11, 12, 13)
Growing urbanization and environmental health challenges.
Public policies on air pollution and energy-related issues.

Knowledge - evaluation of results:
It recognizes that carbon dioxide production is the main driver of anthropogenic climate change.
It defines the concept of primary energy and its sources.
Identifies various forms of energy production and transfer.
Recognizes the difference between renewable and non-renewable energy sources.
Identifies the benefits of using renewable energy and the challenges associated with using renewable energy.
Identifies measures and proposes general actions to combat climate change.

Skills (Capabilities/Competencies)
In general: curiosity, cooperation, critical thinking, self-awareness, citizenship, problem definition, problem solving, analysis and discussion of facts, argumentation, public speaking and presentation, participation in brainstorming, debate, hypothetical-deductive reasoning, inductive reasoning, problembased learning, understanding scientific principles and models, planning and carrying out a researchbased project, critical thinking, teamwork, understanding the applications of mathematical models, risk assessment and decision making.

Specific:
Find, analyze and interpret scientific data, texts and dynamic graphical representations to establish the relationships between energy sources, air pollution and extreme weather events.
It looks at the general process of energy production.
Looks at how energy supply chains impact carbon emissions to the atmosphere.
It looks at the consequences of air pollution in terms of damage to the environment, global warming and extreme weather events.
Looks at the consequences of air pollution for public health.
Understands the environmental and economic impacts resulting from the consumption of the most important energy sources available on the planet.
Obtains, evaluates and communicates facts related to energy sources and their implications for indoor and outdoor air pollution.
Obtains, evaluates and communicates facts related to the public health implications of pollution.

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It looks at the risks at individual and community level associated with emissions of polluting gases into the atmosphere.
It comprises patterns of undesirable behavior in relation to household energy consumption.
It includes strategies to reduce energy waste, such as using renewable energy sources more often and minimizing the ecological footprint.

Competences - assessment of results:
Selects appropriate concepts, indicators and facts to characterize and relate energy sources, and factors that give rise to problems such as air pollution and extreme weather events.
Anticipate the consequences of anthropogenic activities from an individual, community and societal perspective.
Anticipate the consequences of energy waste from an individual, community and societal perspective.
It proposes concrete actions to adopt an environmentally friendly lifestyle in their routines.
You feel able to reduce your own ecological footprint by transitioning to a greener lifestyle (e.g.
using public transport instead of a private car; avoiding the use of wood-burning fireplaces; cycling if possible, among others).
You feel able to influence the adoption of green choices in relation to energy consumption by other people (e.g. family, colleagues, friends).
Anticipates community issues and challenges in relation to SDG 7 (affordable and clean energy) and links them with other SDGs (particularly SDG 3 - health and well-being).

Affective Behavior/Attitudes(beliefs)
Adopts general attitudes towards rationalizing energy consumption.
Take steps to minimize the ecological footprint by reducing energy needs and shifting to more sustainable energy sources.
Build arguments and discuss measures to reduce environmental and household risks, with a special focus on public policies related to SDG 7 (affordable and clean energy).

Attitudes and behavior - Evaluation of results:
Believes that civic-minded and energy-conscious behavior is key to minimizing the loss of air quality in the local community.
Believes that lifestyles influence extreme weather events, emissions of polluting gases into the atmosphere and air quality at community level.
Believes that pollution is an environmental determinant of health.
You disapprove of wasteful energy patterns in your living environment (e.g. inefficient management of basic resources such as water or electricity).
It is committed to addressing issues in the community related to energy supply chain management, energy efficiency and how these factors can influence the incidence of extreme weather events.
Considers that personal and community choices in energy use have impacts on the effectiveness of energy management and on indoor and outdoor pollutant concentrations.
It is committed to communicating and actively participating in community challenges regarding energy consumption.

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Learning objectives and outcomes
Uses online tools to plot tables, graphs and maps, using up-to-date data.
It looks at how the consequences of unaware behavior can contribute to the growing problem of climate change.
Obtain, evaluate and communicate science-based data and information on energy sources, energy production and energy transfer.
It gives examples of how climate change is affecting the planet and community life and well-being.
Use facts to propose measures and methods to efficiently rationalize energy consumption and to communicate them to the responsible bodies within your community.
It describes different approaches to protecting, developing and influencing community health.
You use facts to propose measures and methods to combat climate change and to communicate them to the responsible bodies within your community.

Assessment methods
Outcome assessment o Quantitative - paper questionnaire.
o Qualitative - students' project.

Process evaluation - evaluation of the teaching-learning sequence - observation grid: target audience reach and extension; implementation of the scenario as planned; execution of the learning scenario as expected/organizational issues to be solved; duration of the teaching-learning sequence; number of people exposed; evaluation by level of engagement with the project - students ("Was it fun to do the project?"/Do you think it would be fun to do the project again?")/ "How do you think the project could be improved?").

Content
STEM content
Principle of conservation of energy.
Energy transfer processes (conduction, convection and radiation).
Combustion.
Chemical reactions.
Sustainable Energy Management.
Renewable energy.
Process of Transformation of Primary Energies (Oil, Coal, among others), into Useful and Sustainable Energy (Electricity).
Sources of indoor and outdoor air pollution.
Air pollution as an environmental determinant of health and associated medical conditions.
Analysis of the occurrence of diseases attributable to ambient air pollution.

Non-STEM content
Lifestyles, Urbanization and Climate Change.
Strategies to maintain quality of life and meet basic needs with the lowest possible level of energy consumption.
Strategies to access clean and affordable energy and avoid energy waste.

Digital Learning Objects (LOs) and Digital Educational Resources (DERs)

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New:

Interactive game on primary energies: Respective energy consumption and rationalization. **[LO1]** ▪ Evidence on Primary Energy and its sources (infographic). **(DER1)**

Worksheets **(RSP2)**

Energy consumption and wealth/development of a country (infographic). **(DER3)**

Energy management and production (infographic). **(DER4)**

Renewable energy sources: Advantages of using them (infographic). **(DER5)**

Sources of Air Pollution (infographic). **(RSD6)**

Climate change (infographic). **(DER7)**

Consequences of Climate Change (images, infographic). **(RSP8)**

Consequences of air pollution (images, infographic). **(DER9)**

Strategies to reduce energy waste, fight climate change and cut air pollution (infographic). **(RSD10)**

Available resources (link):

https://www.dropbox.com/sh/o8s73tgwz3g8e43/AAAtG1PaWvmO7TvIxP5JTpzVa?dl=0

From other high quality sources/platforms:

-About Primary Energy Sources (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-worldselectricity-supply/6440/(Hydraulic power). **(DER15)**

- On the concept of Primary Energy and its 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 Generation | 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)**

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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-EnergyTechnologies.pdf(DER33)

- Economic, Social and Environmental Impacts - Related to the consumption of energy sources
https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2016/IRENA_Measuringthe-Economics_2016.pdf(DER34)
https://www.renewableenergymagazine.com/emily-folk/the-many-economic-benefits-ofrenewable-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-theworld/?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
Target Discipline:
Physical chemistry lessons (Physics strand)
7th grade (pupils +/- 12 years)
About 6 lessons of 40-45 minutes
Physics teachers integrate other colleagues in the implementation of the scenario (e.g. science teachers, ICT teachers), as the implementation of the scenario aims to be multidisciplinary.
Topics of each lesson:
Lesson 1: Identify and compare primary energy sources.
Lesson 2: Research, understand and discuss how energy consumption varies throughout the year, month and day.
Lesson 3: Explore combinations of primary energies to meet energy consumption needs.

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Lesson 4: Level of Primary Energy Use in the World.
Lesson 5: Identify measures and behaviors to adopt to rationalize energy consumption without loss of comfort and basic needs.
Lesson 6: Impacts of energy rationalization at different levels.

Lesson 1: Identify and compare primary energy sources
The main objectives to be achieved in this lesson, from the learner's perspective, are the following:
Defines the concept of primary energy and its sources.
Find, analyze and interpret scientific data, texts and dynamic graphical representations to establish relationships between energy sources.

Lesson Summary 1:
In this lesson, the concept of "Primary Energy" and its sources are explored. A contextualization of the school research project will also be made.

Activity 1
The teacher should start the lesson by describing the plan for the next lessons, which are directly related to a school research project. The following topics should be mentioned by the teacher:
Students explore/study concepts related to primary energies and sources available on the planet.
Students study how energy consumptions vary over the years by researching and analyzing credible data and scientific bases.
Learners discuss and explore how we can efficiently meet the consumption needs of households, in an interactive way, through a game where learners combine different primary energy sources to solve the problem at hand and explain the reasons why they chose one source over another.
Students analyze how excessive energy consumption, as well as its waste, impacts society at different levels (from a social, health, environmental and economic perspective), some of the problems being soil and water contamination, air pollution, among others.
Students present a series of measures and recommendations to prevent/mitigate energy exploitation and overconsumption, as well as energy waste in school and community spaces.
Students present the results of the school research project (facts, proposals and recommendations to the community) at the open school event.

➢ **Activity 2**
In lesson 1, as mentioned in the summary, the concept of "Primary Energy" is explored. The teacher describes the main sources of primary energy after promoting a brainstorming activity in the classroom on the topic. The questions to ask in the brainstorming activity could be:
"What is Primary Energy?"
"What are the primary energy sources you know?".

Initially, and to facilitate both the organization of students' ideas and their research, they will be given a worksheet **[DER2]** where there is a field where students indicate their initial responses. These answers allow the teacher to qualitatively assess the students' initial conceptions about the process of the topic in question. The worksheet has another field where students should answer the same questions, but with the information they will find during the research process. Students answer the questions individually and then

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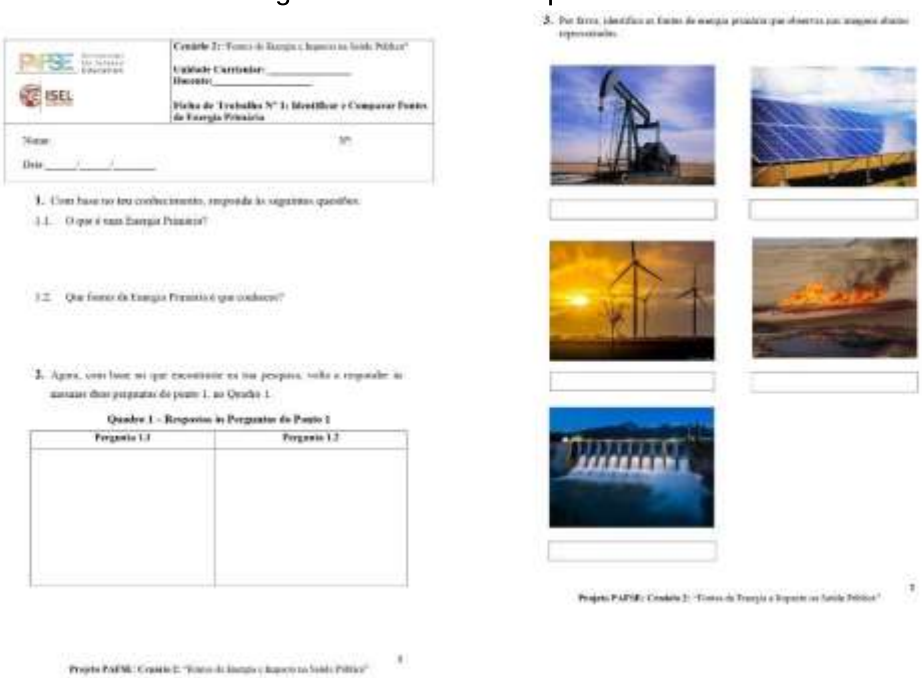
form groups (3/4 students) to discuss their answers and reasoning. The worksheet will also have images of primary energy sources and learners will identify the energy source being displayed. The images that will be on the worksheet can be obtained from the following resources:
https://www.sciencephoto.com/media/339586/view/a-jack-pump-used-for-oil-extraction; (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-worldselectricity-supply/6440/(Hydropower) **(DER15)**

An example of the worksheet to be distributed to the pupils/groups so that they can efficiently organize their ideas and reasoning can be seen in the picture below.



Activity 3

After completing the worksheet (with a time limit set by the teacher for students to complete the worksheet and discuss their reasoning with their group), students are introduced to the main sources of primary energy, such as mechanical energy in the form of hydro and wind power (these being renewable energies), or energy from hydrocarbons (namely fossil fuels such as oil or natural gas). This information can be put together in the form of a PowerPoint presentation (at the teacher's discretion) and can be obtained 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)**
Next, the teacher should address the practical component of the project by presenting students with cards containing the different Primary Energy sources (preparatory activity for the interactive game of lesson 3

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[LO1]). The teacher should discuss the content of these cards so that students, having already analyzed what Primary Energies are, have a general idea of the parameters that characterize these energy sources, and that will be important to carry out the activity of lesson 3. The cards will contain, in addition to the nomenclature of the Primary Energy sources in question, the parameters that characterize the respective energy source, these being the following:
The Chemical Symbol.
SI units.
Calorific value.
CO2 emissions.
Condition at room temperature.
Producing countries.
Forms of storage.
Means of transport.
Efficiency of plants.
Hours of service.
Time out of service.

Activity 4
At the end of the lesson, the teacher proposes to the students to fill in a short quiz on the topic covered in the lesson: students are asked to name some primary energy sources and to make comparisons between them. The questions of the quiz can be: "1. Identify the most appropriate definition of what a primary energy is. A) It is a useful source of energy, which has not undergone any transformation. B) It is a source of energy that can only be obtained from the sea. C) It is a source of any type of energy available in nature before it is converted or transformed." "2. Identify 3 primary energy sources. A) Solar Energy, Electrical Energy, Hydraulic Energy. B) Chemical Energy, Nuclear Energy. C) Electrical energy, Wind energy, Solar energy." "3. Can Electrical Energy be considered a primary energy? A) Yes, because it is a source of energy in its raw form. B) No, because it is a source of energy available in nature before being converted. C) No, because it is an energy source generated from the conversion of a primary energy such as hydro or solar energy." Response:
C)
B)
C)

Students try to answer the questionnaire in groups (preferably in the groups previously formed to fill in the worksheet). During the activity, the teacher circulates around the classroom, supervising and supporting the students' work, asking questions, and providing *feedback* whenever necessary. The teacher notices whether the students have used credible sources of information and the difficulties they faced in obtaining the answers. To get more information on this last question, the teacher can also add the following question to the questionnaire: "What were the main difficulties you faced in the process of searching for information to answer the worksheet and/or questionnaire?".

Learning objects to be used in this lesson:
Facts on Primary Energy and its sources **(DER1)**
Worksheets **(RSP2)**

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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-worldselectricity-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: Research, understand and discuss how energy consumption varies throughout the year
The main objectives to be achieved in this lesson, from the learner's perspective, are the following:
Identifies various forms of energy production and transfer.
Recognizes the difference between renewable and non-renewable energy sources.
Obtain, evaluate and communicate science-based data and information on energy sources, energy production, energy transfer and energy consumption.

Lesson Summary 2:
Lesson 2 expands students' knowledge of the most consumed energy sources in the world and how consumption has varied over the months and years.

Activity 1
Learners are organized in groups to answer the following questions in a brainstorming activity:

"How much energy does the world consume each year?"
"What are the main sources of energy consumed in the world?"
"Is energy consumption the same in all countries, or are there differences?"

Then, to address the problem with regard to the impact that energy consumption has at a societal level, the following questions are posed*:*

"How does energy consumption affect everyday life?"
"Is there a cause/effect relationship between countries' development and energy consumption?"

Initially, and to facilitate both the organization of students' ideas and their research, they will be given a worksheet **[DER2**] where there is a field where students indicate their initial answers. These answers allow the teacher to qualitatively assess the students' initial conceptions about the topic in question. The worksheet has another field where students should answer the same questions, but with the information they will find during the research process. An example of the worksheet to be distributed to the students/groups can be seen in the pictures below.

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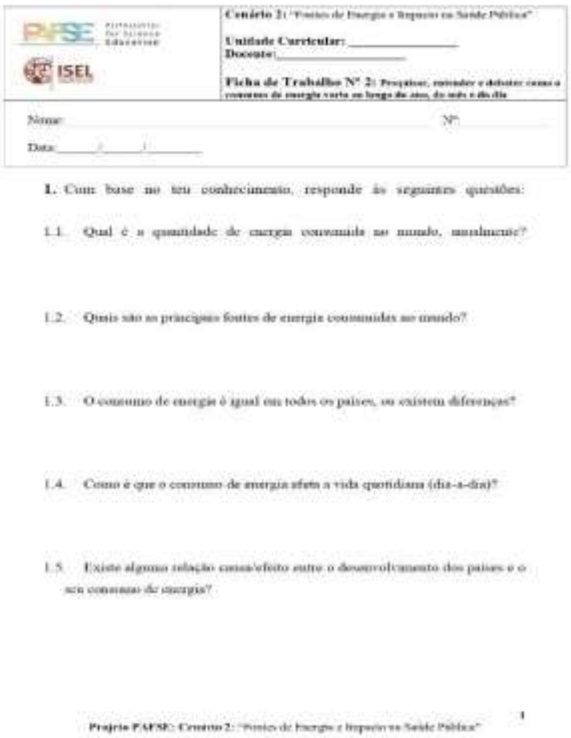


Cenário 2: "Fontes de Energia e Impacto na Saúde Pública"

Unidade Curricular: ______________
Docente: ______________

Ficha de Trabalho Nº 2: Pesquisar, entender e debater como o consumo de energia varia ao longo do ano, do mês e do dia

Nome: ______________ Nº: ______

Data: ____/____/______

1. Com base no teu conhecimento, responde às seguintes questões:

1.1. Qual é a quantidade de energia consumida no mundo, anualmente?

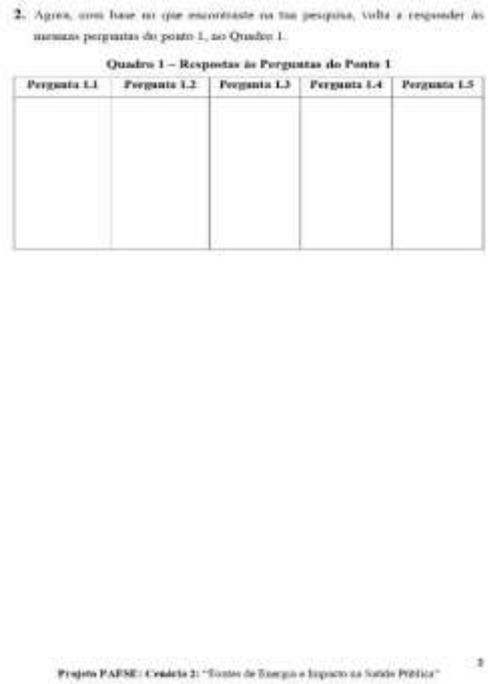
1.2. Quais são as principais fontes de energia consumidas no mundo?

1.3. O consumo de energia é igual em todos os países, ou existem diferenças?

1.4. Como é que o consumo de energia afeta a vida quotidiana (dia-a-dia)?

1.5. Existe alguma relação causa/efeito entre o desenvolvimento dos países e o seu consumo de energia?

Projeto PAFSE: Cenário 2: "Fontes de Energia e Impacto na Saúde Pública" 1



2. Agora, com base no que encontraste na tua pesquisa, volta a responder às mesmas perguntas do ponto 1, no Quadro 1.

Quadro 1 – Respostas às Perguntas do Ponto 1

Pergunta 1.1	Pergunta 1.2	Pergunta 1.3	Pergunta 1.4	Pergunta 1.5

Projeto PAFSE: Cenário 2: "Fontes de Energia e Impacto na Saúde Pública" 2

Learners search for information independently, in reliable sources of information, and then discuss their reasoning in groups (3/4). The teacher then tells the pupils that they should always check the following criteria before taking information as valid: • The source and author of the information.
• The date it was published, as the older a document is, the higher the risk of the information being out of date.
In addition, the teacher encourages students to search for information in reliable databases (e.g. WHO database), in scientific articles, so that these two conditions are guaranteed. During the activity, the teacher circulates around the classroom, and checks if students are having any difficulties in searching and processing information. If this happens, the teacher should provide students with the necessary support elements, and can structure the supporting information on the topic from the following resources:
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 Generation | Statistics Map by Region | Enerdata **(DER23)**
https://afse2017.sciencesconf.org/143355/Article_su.pdf **(DER24)**
- The Many Economic Benefits of Renewable Energy - Renewable Energy Magazine, at the heart of clean energy journalism **(DER35)**
Three Reasons Oil Will Continue to Run the World (forbes.com) **(DER42)**
UKOG - Why oil is important (ukogplc.com **(DER43)**

Activity 2
After carrying out the first research activity, and the internal discussion between the groups about their reasoning (with a time limit set by the teacher for the students to fill in the worksheet and discuss their

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reasoning with their group), the teacher provides the students with credible, organized and systematized information on the topics to be investigated by the students (for this, the teacher prepares a presentation on the topic based on the sources mentioned above, **DER20-DER24, DER35, DER42, DER43**).

Activity 3

At the end of lesson 2, students should fill in a short questionnaire about what they have learned in the lesson. Students indicate which energy sources are most consumed in the world and how energy consumption varies over the years. The following questions are included in the quiz: "1. Identify the most consumed energy source in the world. A) Nuclear energy. B) Solar energy. C) Oil." "2. What is the percentage of electricity that comes from renewable energy sources? A) 5 to 10%. B) 20 to 30%. C) 40 to 50%" "Which continent consumed the most energy in 2021?" A) Asia. B) Europe. C) North America." Response:

C)

B)

A)

Students try to answer the questionnaire in groups (preferably in the groups previously formed to fill in the worksheet). During the activity, the teacher circulates around the classroom, supervising and supporting the students' work, asking questions, and providing *feedback* whenever necessary. The teacher notices whether the students have used credible sources of information and the difficulties they faced in obtaining the answers. To get more information on this last question, the teacher can also add the following question to the questionnaire: "What were the main difficulties you faced in the process of searching for information to answer the worksheet and/or questionnaire?".

Learning objects to be used in this lesson:

Primary Energy Facts and Sources **(DER1)**

Worksheets **(RSP2)**

Facts about energy consumption and a country's wealth/development **(RCD3)**

Energy Management and 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 Generation | Statistics Map by Region | Enerdata **(DER23)**

https://afse2017.sciencesconf.org/143355/Article_su.pdf **(DER24)**

Lesson 3: Explore combinations of primary energies to meet energy consumption needs

The main objectives to be achieved in this lesson, from the learner's perspective, are the following:

Recognizes the difference between renewable and non-renewable energy sources.

Obtains, evaluates and communicates basic scientific data and information on energy sources, energy production and energy transfer.

Disapprove of behaviors such as wasting energy in your living environment.

Take steps to minimize the ecological footprint by reducing energy needs and switching to sustainable energy sources.

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Lesson Summary 3:
In this lesson, students learn how to interactively combine different primary energy sources to efficiently solve a real-life problem through a game. Students will choose a primary energy source or a combination of different primary energy sources to efficiently meet the energy consumption needs of a household.

Activity 1
At this stage, learners already have basic knowledge about Primary Energies, energy sources and energy consumption worldwide. In this sense, they are challenged to combine the different primary energy sources they already know through a game **(LO1).** The groups will have to decide which is the best primary energy source to be transformed into electrical energy, which will be consumed in a household. For this purpose, the cards mentioned in lesson 1, in the 2nd part of activity 3, are distributed to the pupils, and taking into account the characteristic parameters of each Primary Energy (addressed in activity 3 of lesson 1) they will select the most suitable Primary Energy source to solve the problem at hand. A series of cards describing various parameters that characterize each Primary Energy source are distributed to the groups.
The parameters are as follows:
The Chemical Symbol.
SI units.
Calorific value.
CO2 emissions.
Condition at room temperature.
Producing countries.
Forms of storage.
Means of transport.
Efficiency of plants.
Start time.
Time out of service.

Based on the information contained in each card, the groups select the best primary energy source to be transformed into electrical energy to meet the consumption needs of a dwelling. The principle of energy rationalization is promoted and associated with the consequent reduction of energy waste. The game is won by the fastest and most accurate answer. In addition, groups that present valid arguments and answers to the problem should receive 1 point.
In order to facilitate the organization of the students' ideas during the game, a worksheet **(DER2)** will be distributed to them, where they can list, for each energy source, the respective advantages and disadvantages and the arguments that justify the choice of the selected energy source. An example of the worksheet that students will have to fill in during the activity can be seen in the images below.

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Partnerships for Science Education

ISEL

Cenário 2: "Fontes de Energia e Impacto na Saúde Pública"

Unidade Curricular: ________________
Docente:____________________

Ficha de Trabalho Nº 3: Explorar combinações de energias primárias para satisfazer as necessidades de consumo de energia

Nome:____ Nº:___________

Data:_____/_____/_______

1. Com base no que estudaste nas aulas anteriores, e com as informações que se encontram nos cartões acerca dos parâmetros que caracterizam as fontes de Energia Primária, no Quadro 1, assinala para cada fonte de Energia Primária, as vantagens e desvantagens que consideres mais relevantes a realçar, tendo em conta o problema que tens de resolver. Na coluna à frente, escreve os argumentos que te fizeram escolher/desprezar cada fonte de energia que te foi apresentada.

Quadro 1 – Vantagens e Desvantagens das Fontes de Energia Primária

Fonte de Energia Primária	Vantagens da Sua Utilização	Desvantagens da Sua Utilização	Argumentos que Justificam a Seleção/Desconsideração

1

Projeto PAFSE: Cenário 2: "Fontes de Energia e Impacto na Saúde Pública"

Learning objects to be used in this lesson:
- Interactive game on primary energies and energy consumption and rationalization **(LO1)** - Worksheets **(RSP2)**

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Lesson 4: Level of primary energy use in the world
The main objectives to be achieved in this lesson, from the learner's perspective, are the following:
Recognizes the difference between renewable and non-renewable energy sources.
Obtain, evaluate and communicate science-based data and information on energy sources, energy production and energy transfer.
It recognizes that carbon dioxide production is the main driver of anthropogenic climate change.
Selects appropriate concepts, indicators and facts to characterize and relate energy sources, causes of air pollution and climate change.

Summary of Lesson 4:
Lesson 4 explores how different energy sources are used around the world, as well as the main differences between them.
Activity 1
At the beginning of the lesson, a series of questions are posed to the students during a brainstorming activity. The aim is for the teacher to get to know the students' initial ideas about the energy sources consumed in the world and main differences. Such questions can be:
1. "What are the main differences between a non-renewable energy and a renewable energy?", 2. "Can renewable energy sources produce the same amount of energy as non-renewable sources?".

To approach the topic the teacher can even use a comparison between 2 representative Energies of each of the cases (Renewable and Non-Renewable Type Energy), for example "Oil Vs Solar Energy", and propose to the students to list the advantages and disadvantages of each of these types of energy. This distinction will address issues related to energy consumption, climate change, and how the use of renewable energy can help combat the problem. In addition, other questions may be asked:
"How can the use of renewable energy help fight climate change?"
"Can we establish a correlation between fossil fuel use and air pollution and climate change?"

These questions, or others that the teacher deems appropriate in the context of the lesson, are presented to the students in the form of a worksheet **(RSP2)**. An example of the worksheet to be distributed to pupils/groups so that they can efficiently organize their ideas can be seen in the images below. Learners search for information independently, in reliable sources of information, and then discuss their

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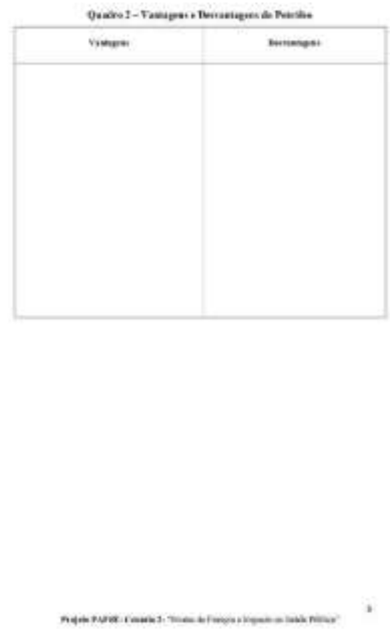

reasoning in groups (3/4). The teacher then tells the pupils that they should always check the following criteria before taking information as valid:
The source and author of the information.
The date it was published, as the older a document is, the higher the risk of the information being out of date.
In addition, the teacher encourages students to search for information in reliable databases (e.g. WHO database), in scientific articles, so that these two conditions are guaranteed. During the activity, the teacher circulates around the classroom, and checks if students are having any difficulties in searching and processing information. If this happens, the teacher should provide students with the necessary support elements, and can structure the supporting information on the topic from the following resources:
Renewables in Electricity Production | Statistics Map by Region | Enerdata **(DER23)**
https://www.empower-solar.com/blog/the-advantages-disadvantages-of-switching-to-solarenergy/
(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-EnergyTechnologies.pdf(DER33)

Activity 2

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Following the group work, the teacher uses resources **RSP5, RSP6, RSP7** and **RSP8**, to explain the advantages and disadvantages gained from the consumption of different energy sources, making a clear distinction between renewable and non-renewable energy sources. The teacher explores the impact of using each of the sources and explains their current level of use/consumption. To facilitate the presentation of this information, the teacher can develop a PowerPoint presentation that integrates the contents of resources **RSP25** to **RSP33**.

Activity 3
The teacher proposes to the students to fill in a short questionnaire about the topics covered in class. The suggested questions are: "1. Identify one advantage of using renewable energy sources. A) Renewable energy sources produce more CO2 emissions than non-renewable energy sources. B) Renewable energy reduces the emission of harmful air pollutant gases. C) Renewable energy sources produce more electricity compared to non-renewable sources." "2. Does the use of renewable energy affect air quality? A) Yes, one of the main advantages of using a renewable energy source, also called a "clean energy source" is that you can significantly reduce carbon dioxide emissions into the atmosphere and improve air quality. B) No, renewable energy sources compared to non-renewable sources are associated with more carbon dioxide emissions into the atmosphere and decreased air quality. C) No, because renewable energy sources emit carbon to the atmosphere in similar concentration as non-renewable energy sources and therefore do not affect air quality."

Response:
B)
A)

Students try to answer the questionnaire in groups (preferably in the groups previously formed to fill in the worksheet). During the activity, the teacher circulates around the classroom, supervising and supporting the students' work, asking questions, and providing *feedback* whenever necessary. The teacher notices whether the students have used credible sources of information and the difficulties they faced in obtaining the answers. To get more information on this last question, the teacher can also add the following question to the questionnaire: "What were the main difficulties you faced in the process of searching for information to answer the worksheet and/or questionnaire?".

Learning objects used in this lesson:
Worksheets **(RSP2)**
Renewable Energy Sources and the advantages of their use **(RCD5)**
Facts on Air Pollution Sources **(RSP6)**
Climate Change Facts **(RSD7)**
https://www.empower-solar.com/blog/the-advantages-disadvantages-of-switching-to-solarenergy/ **(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)

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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)

Lesson 5: Identify measures and behaviors to rationalize energy consumption without loss of comfort and basic needs

The main objectives to be achieved in this lesson, from the learner's perspective, are the following:
Identifies measures and proposes general actions to better rationalize energy consumption.
Use facts to build arguments about energy rationalization.
Anticipate the consequences of anthropogenic activities such as energy exploitation and overconsumption from an individual, community and societal perspective.
Anticipate the benefits of energy rationalization from an individual, community and societal perspective.

Lesson summary 5:

In lesson 5 a discussion should be promoted with the students on the need to change energy consumption habits in the general population in order to reduce some of the problems identified in the previous lessons, such as climate change or air pollution.

Activity 1

The students are organized in the groups formed in the previous lessons and the teacher proposes a classroom debate on the topic "Reducing energy consumption in a house", considering the energy consumption in the different rooms of the house and the behaviours of its inhabitants. In order for the debate to be conducted effectively, the teacher should discuss the rules of the debate and ensure that they are followed:

The main focus of the debate:

The main focus of the discussion is "Reducing energy consumption in a house", considering energy consumption in different rooms of the house and behaviors of the inhabitants. Learners use the knowledge acquired in the last lessons and substantiate ideas/proposals to reduce energy consumption in homes. They then present the measures they have selected to solve the problem/need.

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PAFSE Partnerships for Science Education ISEL	**Cenário 2:** "Fontes de Energia e Impacto na Saúde Pública" **Unidade Curricular:** ________________ **Docente:**____________________ **Ficha de Trabalho Nº 5: Identificar medidas e comportamentos para racionalizar o consumo de energia sem perda de conforto e necessidades básicas**
Nome:______________________________________	Nº:____________
Data:_____/_____/_______	

1. Com base no que já estudaste, no Quadro 1 enumera todas as medidas que consideres adequadas para reduzir eficientemente o consumo de energia na habitação em questão, sem que isso implique a perda de conforto ou necessidades básicas dos habitantes. No mesmo quadro, enumera também todos os argumentos que te levaram a escolher cada medida.

Quadro 1 – Medidas a Aplicar para Resolver o Problema em Questão

Medidas a Aplicar
Argumentos que Justificam as Medidas Selecionadas

Projeto PAFSE: Cenário 2: "Fontes de Energia e Impacto na Saúde Pública" 1

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101006468.

The structure of the debate:
To carry out the debate, the teacher divides the students into groups (4-5 students), and each group is given time to select the measures they consider most appropriate, based on the scientific data collected in the last lessons, and in the practical activity of lesson 3. To facilitate their reasoning, they will be given a worksheet **[RSD2**] where there is a field where students indicate the measures they consider most appropriate, and another field where they identify the arguments (**RSD10)** that justify their selections. Images, data, graphs, infographics can be constructed or taken from other credible sources of information to support the argumentation developed. An example of the worksheet to be distributed to students/groups can be observed in the image illustrated below.

The rules of the debate:
Each member of each group must speak at least once, and the order and content of the speech is discussed in advance by the group members. After each group presents its measures, the other groups present their counter-arguments. The group that has just presented is then given time to rebut these counterarguments. The presentation of the counter-arguments to the proposals made by colleagues should be made by only 1 member of each group, indicated by the teams. If the other groups agree with the arguments of the group that has just presented, they should present at least one suggestion or recommendation to the measures that have been mentioned by the group that has just presented.

Evaluation of the debate:
The evaluation of the debate is at the discretion of the teacher, but must involve the following criteria:
The group that submitted the best proposals.
The group that best defended its point of view.
The group that best refuted the arguments of the other groups.

➢ **Learning objects to be used in this lesson:**
Worksheets **(RSP2)**
Strategies to cut energy waste, fight climate change and tackle air pollution (infographic). **(RSP10)**

Lesson 6: Impact of energy rationalization on public health and other sectors of society
The main objectives to be achieved in this lesson, from the learner's perspective, are the following:
Anticipate the consequences of anthropogenic activities from an individual, community and societal perspective.
Looks at the consequences of air pollution for public health.
Understands the environmental and economic impacts of consuming the planet's available energy sources.
Obtains, evaluates and communicates facts related to the consumption and exploitation of energy sources and their implications in terms of indoor and outdoor air pollution.

Summary of Lesson 6:
In lesson 6, the teacher exploits the knowledge developed from the previous lessons to explain the influence of energy rationalization on different levels, such as economic, social, environmental, giving special interest to the impacts that the rationalization of energy consumption can have on public health. This lesson also defines the work plan for the school research project.

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Activity 1

The students are distributed in the previously formed groups and research on the impacts that energy rationalization and the use of more sustainable energies have at various levels, such as economic, social or environmental, giving special interest to the impact that the rationalization of energy consumption can have in solving public health problems, such as air pollution or climate change.

The information that each group collects will be discussed and selected by the group in consensus. A worksheet **(RSD2)** will be given to them, where there will be several fields related to each level (economic, social, environmental, etc...) in which the students indicate the impacts they found in the research for each of these levels. An example of the worksheet to be distributed to the groups can be seen in the image below.

PAFSE Partnerships for Science Education ISEL	**Cenário 2:** "Fontes de Energia e Impacto na Saúde Pública" **Unidade Curricular:** ______________ **Docente:** ______________ **Ficha de Trabalho Nº 6.1: Impacto da Racionalização Energética a Diversos Níveis**

Nome: ______________________________ Nº: __________

Data: ____/____/______

1. Com base no que já estudaste, no Quadro 1 enumera os principais impactos a diferentes níveis decorrentes da utilização de energias sustentáveis.

Quadro 1 – Impactos da Utilização de Energias Sustentáveis

Nível Económico	Na Saúde Publica	Nível Ambiental

Projeto PAFSE: Cenário 2: "Fontes de Energia e Impacto na Saúde Pública" 1

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Learners search for information independently, in reliable sources of information, and then discuss their reasoning in groups (3/4). The teacher then tells the pupils that they should always check the following criteria before taking information as valid: • The source and author of the information.
• The date it was published, as the older a document is, the higher the risk of the information being out of date.
In addition, the teacher encourages students to search for information in reliable databases (e.g. WHO database), in scientific articles, so that these two conditions are guaranteed. During the activity, the teacher circulates around the classroom, and checks if students are having any difficulties in searching and processing information. If this happens, the teacher should provide students with the necessary support elements, and can structure the supporting information on the topic from the following resources:

Non Renewable Energy - Advantages and Disadvantages of Non Renewable Energy (vedantu.com) **(DER27)**
Renewable energy - powering a safer future | United Nations) **(DER29)**
Fossil fuels-facts and information (nationalgeographic.com**(DER30)**
- The Many Economic Benefits of Renewable Energy - Renewable Energy Magazine, at the heart of clean energy journalism **(DER35)**
Usage of Energy Sources and Environmental Problems (sagepub.com **(DER37)**
Conflicts - Oil Exploration and Water - PMC (nih.gov) **(DER43)**
https://www.eea.europa.eu/publications/healthy-environment-healthy-lives (**DER50)**

Note: In the RSP50, it is possible to look specifically at the impacts that environmental pollution can have on human health and quality of life. In particular, chapter 4 of the paper is exclusively dedicated to this issue. Chapter 3 provides a detailed overview of the benefits of green environments.

Activity 2
After carrying out the research activity, and the internal discussion between the groups about their reasoning (with a time limit set by the teacher for the students to fill in the worksheet of activity 1 and discuss their reasoning with their group), the teacher provides the students with credible, organized and systematized information on the topics to be investigated by the students (for this purpose, the teacher prepares a presentation on the topic based on the sources mentioned above, **RSD27,RSD29, RSD30, RSD35, RSD37, RSD43** and **RSD50**).

Activity 3
In this activity the objectives of the school research project are discussed. The teacher mentions that the project challenges each group to create and present an infographic/PowerPoint presentation that summarizes: : a) What they have learned throughout the teaching-learning sequence; b) Actions/measures to reduce energy consumption at the school community level; c) Relevant environmental and public health outcomes from the implementation of such measures.
Learning Objects used in this lesson:
Worksheets **(RSP2)**
Non Renewable Energy - Advantages and Disadvantages of Non Renewable Energy (vedantu.com) **(DER27)**
Renewable energy - powering a safer future | United Nations) **(DER29)**

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Fossil fuels-facts and information (nationalgeographic.com**(DER30)**
- The Many Economic Benefits of Renewable Energy - Renewable Energy Magazine, at the heart of clean energy journalism **(DER35)**
Usage of Energy Sources and Environmental Problems (sagepub.com **(DER37)**
Conflicts - Oil Exploration and Water - PMC (nih.gov) **(DER43)**
https://www.eea.europa.eu/publications/healthy-environment-healthy-lives (**DER50)** -
https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2021EF002558 **(DER48)** ➢

Complementary Activity

In order to reinforce the students' knowledge, as a complementary activity to those developed in class 6, it is proposed that students carry out 2 activities. One, where the objective is to make students aware of how to combat air pollution and climate change, through the rationalization and efficient use of energy, and how the so-called "clean energies" and the civic behavior of the population have a fundamental role in mitigating these problems **(DER10)**. In the 2nd complementary activity, learners propose a series of measures to be implemented, both at individual and community level, to reduce energy consumption in their homes, making them more sustainable from an energy point of view **(RSP10).** For these activities to be conducted, the following sequence of activities is proposed:

Activity 1

The aim of this activity is to make students aware of how to fight air pollution and climate change through rationalization and efficient use of energy, and how so-called "clean energies" and civic behavior of the population play a key role in mitigating these problems **(RCD10)**. The teacher asks the groups to develop a research activity on how the control of primary energies influences the global economy. The teacher approaches this question through a brainstorming activity. The questions of this activity can be:

"How does control of commodities influence the global economy?"
"What is the level of air pollution in countries that use mainly renewable energy compared to those that use mostly fossil fuels?" **(RSP9).**

In order to facilitate the organization of the students' ideas and the research they will carry out, a worksheet **(DER2)** is distributed, where the students write the answers to the above questions. An example of a worksheet to be distributed can be seen in the image below.

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PAFSE Partnerships for Science Education ISEL	**Cenário 2:** "Fontes de Energia e Impacto na Saúde Pública" **Unidade Curricular:** ________________ **Docente:**____________________ **Ficha de Trabalho Nº 6.2: Impacto da Racionalização Energética a Diversos Níveis**
Nome:____	Nº:_____________
Data:______/______/________	

1. Com base no que já estudaste, por favor responde às seguintes perguntas:

1.1. Como é que o controlo das energias primárias pode influenciar a nossa vida e a economia no geral?

1.2. Como é que está o nível de poluição do ar nos países que utilizam principalmente energia renovável, em comparação com aqueles que usam maioritariamente combustíveis fósseis (energias não renováveis)?

Projeto PAFSE: Cenário 2: "Fontes de Energia e Impacto na Saúde Pública" 1

Learners search for information independently, in reliable sources of information, and then discuss their reasoning in groups (3/4). The teacher then tells the pupils that they should always check the following criteria before taking information as valid:

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The source and author of the information.
The date it was published, as the older a document is, the higher the risk of the information being out of date.
In addition, the teacher encourages students to search for information in reliable databases (e.g. WHO database), in scientific articles, so that these two conditions are guaranteed. During the activity, the teacher circulates around the classroom, and checks if students are having any difficulties in searching and processing information. If this happens, the teacher should provide students with the necessary support elements, and can structure the supporting information on the topic from the following resources:

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-runthe-world/?sh=2026a72143f9 **(DER42)**

➢ **Activity 2**

Pupils propose a series of measures to be implemented, both at individual and community level, to reduce energy consumption in their homes, making them more energy sustainable **(RSP10).** The activity is started in class and completed outside of class. Learners should refer to facts that relate energy consumption, air pollution and public health consequences, as well as the environmental and economic impacts of the most important energy sources available on the planet. In addition, students should establish a link between human-driven overexploitation of energy and the resulting consequences for wildlife, the environment and public health, such as increased incidence of chronic respiratory diseases, cardiovascular diseases and cancer. They should mention the main problems arising from excessive energy exploitation, such as soil and water contamination, air pollution, among others (**RCD8, RCD9).** In order for students to organize their ideas and reasoning, a worksheet **(RSP2)** will be distributed to them (to the groups formed in the previous lessons). An example of the worksheet to be distributed can be seen in the pictures below.

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	Cenário 2: "Fontes de Energia e Impacto na Saúde Pública" **Unidade Curricular:** ____________ **Docente:**_______________ **Ficha de Trabalho Nº 7: Projeto de Pesquisar Escolar**
Nome:______________________________ Nº_________ Data: ____/____/______	

1. Com base no que estudaste, refere agora no Quadro 1, para cada fonte de energia primária analisada, as vantagens e desvantagens do uso/exploração dessa energia para a saúde pública.

Quadro 1 – Impactos da Utilização/Exploração de Energias Primárias para a Saúde Pública

Fonte de Energia Primária	Vantagens da Sua Utilização/Exploração	Desvantagens da Sua Utilização/Exploração

Projeto PAFSE: Cenário 2: "Fontes de Energia e Impacto na Saúde Pública" 1

2. Tendo, na mesma, em consideração aquilo que estudaste, indica agora no Quadro 2, medidas que podes aplicar na tua comunidade escolar, e que permitem reduzir o desperdício energético energia através da racionalização eficiente do consumo de energia, tornando, por sua vez, o ambiente mais sustentável. Como ponto de partida, podes olhar para as medidas que indicaste no debate da aula 5 para reduzir eficientemente, o consumo de energia numa determinada habitação.

Quadro 2 – Medidas a Aplicar na Comunidade Escolar

Medidas a Aplicar
Argumentos que Justificam as Medidas Selecionadas

Projeto PAFSE: Cenário 2: "Fontes de Energia e Impacto na Saúde Pública" 2

Some data that can assist students in carrying out this task can be obtained 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/wpcontent/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)**

Note: The completed sheets should be kept by the teacher and used in the realization of the school research project.

Supplementary learning resources and educational activities

Invite STEM organizations.
Discuss energy consumption within households and organizations, climate change and the impact of these issues on public health.
Discuss energy facts with environmental NGOs, social NGOs, government, EU and the rest of the world.

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Preliminary discussion on how countries produce energy.
Compare the primary energies available in each country.
Compare the energy efficiency measures implemented in each country.
Discuss the Governments policy for energy rationalization.
Discuss measures to reduce air pollution and extreme weather events. ▪ Interact with STEM professionals.

<u>School Research Project</u>
Topics
Energy sources in systems and their relationship.
Direction in which each energy is transferred.
Renewable energies (advantages and disadvantages of their use and consequences for the Earth's sustainability, interdisciplinary perspective).
Difference between temperature and heat, relating them through examples.
Measures promoting rational use of energy.
Consequences for the environment due to the emission of pollutants resulting from combustion reactions; mitigation and adaptation measures.
Climate change as one of society's current major problems.
Link between air pollution and climate change.
Air pollution as an environmental determinant of health.

Research management, design and administration
Challenge: build a poster or infographic on Energy Rationalization!

Method (summary): learners are organized in groups; each group addresses strategies to promote energy rationalization in their school. The project challenges each group of learners to create and present an infographic that synthesizes: a) What they have learned throughout the teaching-learning sequence; b) Actions/measures to reduce energy consumption at the school community level; c) Relevant environmental and public health outcomes from the implementation of such measures.
Following this process, by the end of the project, students will have understood the importance of rational energy use and its global impacts

Development process: Based on the knowledge acquired in the previous lessons, the students try to come up with a series of actions/measures to be adopted by the school community to rationalize energy consumption.
In the development of the project, students make observations of the infrastructure of the school community and the behavior of people on the topic of "energy consumption". The teacher discusses with the students possible questions to analyze the school's attributes and patterns in terms of energy consumption and presents possible methods to obtain the answers. The advantages and limitations of the alternatives presented are discussed. Next, a brainstorming activity is promoted where possible starting questions to address the topic are launched by the teacher: 1. Are there solar panels in the school? 2. Is there any strategy in place to save energy? 3. 3. Is there any strategy in place to avoid water waste? 4. Is there any strategy in place to create a more sustainable environment in the school? 5. What are the energy consumption needs of the school?

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The outcome of the project will be a survey of the school's strengths and weaknesses on the topic and definition of proposals to be adopted by the school community. The guiding thread of the actions and recommendations is to mitigate long-term risks (e.g. escalation of the climate change problem, increase in air pollution, increase in the incidence of chronic respiratory diseases, illnesses, among others). Proposals related to energy rationalization should be systematically linked to the benefits that the changes could bring to the health and well-being of the school community.

Objectives of the teaching-learning process:
Students will be able to:
Develop critical thinking (e.g. analyse, organize, discuss and share information related to lesson 3 - learners are asked to meet the energy consumption needs of households with various primary energy sources at their disposal).
Develop digital skills (e.g. find, review and use quality online resources to develop the activities).
Understand the concept of "Primary Energy" and its importance.
Understand the concepts of "Production, Transfer, and Conservation of Energy" and their importance.
Understand the impact at different levels (e.g. economic, social, health) of energy exploitation and overconsumption, as well as energy waste.
Develop the ability to construct arguments and counter-arguments in order to make decisions on social-scientific issues.
Develop the ability to debate socio-scientific issues.
Investigate community perceptions and knowledge about energy waste and excessive energy consumption.
Developing responsible citizenship and health literacy.

Teaching-learning process for school design (abstract):
Collecting facts (data, information, articles, photos).
Evaluation of facts based on criteria and selection of relevant and non-biased information.
Development of criteria for evaluating arguments.
Preparation of a calendar of tasks for the open school event.
Creation of a poster/PowerPoint presentation related to measures to be taken to efficiently meet energy consumption needs in different environments (e.g. school, home) for presentation at the open school event.

Organization of the open school event:
Each project outcome (brochures/presentation) is presented by the learners in a relevant community setting (e.g. exhibition center, municipality, garden, museum, science fair).
Students will communicate the selected measures to promote energy rationalization in their school using scientifically based argumentation. Students call for everyone's action to improve the health of the community, providing a broad understanding that preventing energy waste is everyone's responsibility, not just that of the government and municipalities.
Stakeholders understand how energy waste is influenced by individual behavior and environmental factors. They also gain high-level knowledge on strategies to minimize energy poverty and how they can influence relevant environments (e.g. home, school, workplace, public space).

Data analysis and reporting Data filtering.

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Define the minimum representative data collected.
Categorization of data.
Data presentation formats.
Internal presentation.
Drafting of the report.
Develop and create communication material.

Target audience for recommendations - Social NGOs.
Policymakers.
General public.
Social Communication.
Families.
Friends.

Public Debate and Recommendations (based on the survey results) Matches between schools with similar environment: compare choices.
Games between schools with different environments: understand the links and how the European Energy Market works.
Discussion and feedback.
Produce information to be communicated in Public Debate.
Make recommendations for reducing energy consumption.
Dissemination of the final report and recommendations on the school website.

2.6.3. Noise pollution and quality of life

Main partner responsible
ISEL

Context

Noise is a social problem, particularly observed in urban environments and in the workplace, with well-documented public health impacts. People's exposure to noise can negatively affect an entire day's work, or even a night's sleep, leading to problems such as reduced day-to-day productivity, loss of health and quality of life. According to the World Health Organization, noise pollution is one of the main 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 preservation of wildlife, and the health and well-being of humans, public debates on the subject should be held frequently, and actions to monitor sound levels in specific situations/contexts/environments are also recommended, comparing the recorded values of measurements with the limits recommended/imposed by current legislation. This scenario provides learners with an *online* tool that allows the *upload* of audio files for sound playback and analysis based on histograms and spectrograms with the indication of frequency and amplitude values. Additionally, the tool also displays a table with the risks associated with public health for each recorded sound frequency and amplitude, as well as in relation to the time of exposure to noise, based on scientific studies and legislation in force. Thus, the learning scenario prepares young people to measure noise levels in various environments and raises their awareness about noise exposure risk

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environment, sources of noise pollution and how noise issues can affect health and quality of life in the community.

Estimated duration

6 lessons of 40-45 minutes (lesson 1 - lesson 6).
6 sessions of 40-45 minutes for the 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 groups of four or five members to develop the school research project. The use of a computer is required.

Prerequisite knowledge and skills

Computer use and basic knowledge of the Microsoft Office software package will be required, as well as knowledge of English (basic level).

Content Glossary

Amplitude- In physics it is the magnitude of an oscillatory quantity, measured from its equilibrium position, e.g. sound pressure or vibration. Amplitude is also the y-axis of the waveform in time and the spectrum.
Decibel- It is used to express the ratio between two physical quantities (relative unit), it is a relative quantity, dimensionless. It can apply to absolute quantities (e.g. electrical power or sound pressure) or to a gain/attenuation (e.g. gain of a sound amplifier). A magnitude in decibel formally corresponds to ten times the logarithm in base ten of the quotient between the physical quantity in question and a reference of the same type.
Frequency- It is the number of times a periodic function or vibration occurs or repeats in a specified time, usually 1 second - cycles per second. It is usually measured in Hertz (Hz).
Frequency f, wavelength λ, speed of sound and period T are related by the expressions $\lambda = v/f$ and $f = 1/T$.
Sound Pressure- is the change in static pressure of any medium in the presence of a sound wave. The particles of the medium, elastic, oscillate around a state of equilibrium. The unit in SI is the Pascal (Pa). Humans can perceive sounds ranging from 0.00002 pascals to 200 pascals, meaning that the pascal is not practical for everyday use.
Sound Pressure Level - is the sound pressure measured in decibels, to compress the huge range of values in Pascal that we can hear.
Noise - This is defined as any sound that is unwanted/uncomfortable for the listener. Any sound that does not occur in the natural environment, such as sounds emanating from aircraft, highways, industrial, commercial and residential sources. Interference of an electrical or acoustic nature. There is no distinction between noise and sound, as both are vibrations that propagate in a medium, whether gaseous, liquid or solid.
Signal-to-Noise Ratio - is the ratio of the power of the signal of interest to the power of the noise. It is usually expressed in dB, so it is the difference between the measured sound level and the noise level due to other sources present.
Noise pollution - is unwanted or excessively loud sound that can have severe consequences for human health, wildlife, and environmental quality. Noise pollution is typically generated within many industrial facilities and some workplaces, but can also originate from road, rail and air traffic and construction

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activities.
Period- Period refers to the time it takes to accomplish something. Frequency and period are different but related parameters. Frequency refers to the number of times something happens in a given observation time. Period refers to the minimum time until something happens. Frequency is a quantity of variation. Period is a quantity of time. Frequency is measured in cycles/second or Hertz. Period is measured in seconds. In Physics, the period is the time required for a complete cycle of vibration to occur. The period is only used in quantities that are repeated, periodic quantities.
Sound- It is a pressure wave that is created by a vibrating object creating an auditory sensation in living beings. These vibrations set particles in motion in the medium where they propagate, carrying energy through the medium. Although there are several types of acoustic waves, the most common are longitudinal waves, as the particles oscillate in the direction of the wave propagation.
Speed of Sound- is the distance traveled per unit time by a sound wave when propagating through an elastic medium. The speed of sound in air is about 343 meters per second for a temperature of 20°C.
Timbre - attribute of auditory sensation that allows the listener to judge that two non-identical sounds with the same intensity and fundamental frequency are different. Timbre depends mainly on the waveform of the sound, but also on the sound pressure and temporal characteristics of the sound. This fact allows, for example, to distinguish between the sound of a piano and a saxophone.
Broadband noise - sound with spectral energy distributed over a wide frequency band.
Tonal Noise - sound with tonal characteristics, i.e. whose spectrum is concentrated in a very narrow frequency band, approximating a sinusoidal signal.
Impulsive Noise - sound with very short temporal duration. This type of signal has a broadband spectrum but a short duration.
Equivalent Continuous Sound Level (Leq, T)- is the value of the sound pressure level of a uniform noise which, over a time interval T, has the
the same effective sound pressure value as the noise under consideration whose level varies with time.
Vibration- Is the oscillating, alternating or other periodic motion of a body, rigid or elastic medium from a position or state of equilibrium. It may also be defined as the analogous motion of the particles of a mass of air in an elastic or similar medium whose state of equilibrium has been disturbed, as in the process of sound transmission.
Wave- is the transfer of sound energy due to the vibration of the particles of the various media through which the sound waves pass. The transmission medium will absorb, reflect or impede the flow of sound energy according to the acoustic properties of that medium and the wavelength of the sound wave. In air there is little resistance (acoustic impedance) to the propagation of sound, in a vacuum, if there are no particles, sound cannot propagate.
Wavelength - is the distance between two consecutive maxima of a sound wave. At 20 Hz the wavelength ≈ 17 m and at 20 kHz the wavelength is ≈ 17 mm (in dry air at 20 °C). Wavelength(λ) for a sound wave = c/f, where c is the speed of sound (343 m/s in dry air at 20 °C) and f is the frequency - units are meters.
General Noise Regulation (RGR)- was established by Decree-Law no. 9/2007 and applies to permanent or temporary noisy activities.
Neighborhood noise - encompasses all noise that is made indoors but that bothers neighbors. The RGR sets out the time periods when noisy activities are prohibited.
Exposure to Noise at work - the Community Directive No 2003/10/EC of the European Parliament and of the Council of 6 February 2003 on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (noise).

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Pedagogical glossary

Active learning. A teaching and learning approach that "engages students in the learning process through activities and/or discussion in class, rather than just hearing theoretical concepts from the expert. This type of learning emphasizes critical thinking and often involves group work".

Brainstorming. *Brainstorming* is an instructional technique with several variations, which can be carried out in groups or with the whole class. During *brainstorming*, all learners quickly express their ideas or concepts that they think are relevant to a given question or basic concept. Scrutiny of the ideas presented is not carried out during *brainstorming* where the aim of the activity is to produce several divergent ideas/viewpoints on the same topic.

Collaborative learning. Collaborative learning is a didactic model that involves a set of pedagogical techniques, during which learners cooperate and/or collaborate during the learning process, as opposed to using the traditional teaching methodology used in schools. Collaborative learning can improve learning outcomes, learners' level of interest and participation, as well as their collaboration and communication skills.

Debating technique. A verbal technique used to involve a group in a particular topic that will be presented/debated. This technique consists in dividing the class into several groups where each one participates in the discussion of a general topic and in building a "general commitment" among all.

Teamwork. Deepens knowledge, develops research and problem-solving skills; develops participation/intervention, cooperation and creativity skills; develops teamwork attitudes, social skills and knowledge.

Quiz-based learning. Inquiry-based learning with the participation of learners in learning activities during which they develop various scientific inquiry skills. Learners make use of these skills to answer scientific questions posed by the learners themselves or by the teacher, and through the treatment/analysis of experimental data collected by themselves or obtained through other sources. Some common research skills include building and using models, conducting experiments, collecting and organizing data, manipulating variables, drawing conclusions from data processing, and communicating about scientific issues.

Project-based learning. Project-based learning is a pedagogical model of active learning. It has several strands, during which learners work in groups to develop projects, which often refer to problems or situations with conditions close to those we encounter in real life. Project-based learning includes the phases of initiation, development and presentation of the project.

Sources: https://www.britannica.com/;Public Health Agency of Canada; EuroHealthNet; National Library of Medicine

Indicative Literature

WHO, Health topic-Noise, https://www.who.int/europe/health-topics/noise#tab=tab_1

Singh, N., & Davar, SC (2004). *Sources, effects and control of noise pollution. Journal of Human Ecology,* 16(3), 181-187.

Murphy, E, & King.A, E. (2022). *Environmental noise pollution, noise mapping, public health and policy*, Second Edition, Elsevier. - ISBN: 9780128201015

Competences / Learning Goals

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Key competencies
STEM/ personal, social

Knowledge
Physics concepts:
Sound.
Noise.
Timbre.
Decibels.
Sound Wave.

Environmental health concepts:
Environmental determinants of health.
Noise, health impacts.
Noise, and its sources.
Noise as a risk factor for quality of life.

Concepts of epidemiology and health economics:
Indicators of loss of quality of life due to noise (e.g. decreased productivity at work, school, etc.).

Social and global health concepts:
Sustainable Development Goals (SDG 3 in relation to other SDGs).
Growing urbanization and the challenges for environmental health.
Public policies on noise and their determinants.
Relationship between lifestyle and noise (health determinants).

Knowledge - evaluation of results:
Distinguish noise from sound.
Defines the units and parameters that characterize the noise variable.
Characterize the public health impacts of regular noise exposure.
Identifies approaches that reduce/mitigate noise exposure and measurement equipment.
Identifies relevant actions to address the challenges related to harmful noise exposure for community health and social life.

Skills (Capabilities/Competencies)
In general: curiosity, cooperation, critical thinking, self-awareness, citizenship, problem definition, problem solving, analysis and discussion of facts, argumentation, public speaking and presentation, participation in brainstorming, debate, hypothetical-deductive reasoning, inductive reasoning, problem-based learning, understanding scientific principles and models, planning and carrying out a research-based project, critical thinking, teamwork, analysis and understanding of tables, spectral density diagrams, understanding the applications of mathematical models, risk assessment and decision making.

Specific:

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Find, analyze and interpret spectra and spectral density curves.
Researches, discusses and communicates facts about the detrimental effects on wildlife and human health resulting from noise exposure.
Looks at practical strategies to reduce noise exposure.
Analyzes scientific facts to explain phenomena related to noise/noise pollution and produces argumentation.
Understands the importance of using a computational tool to solve everyday problems.

Competences - assessment of results:
Select appropriate concepts, measures and indicators to measure noise levels.
Anticipate the consequences for wildlife and human health of regular exposure to noise pollution.
Proposes concrete actions/measures to reduce noise exposure in your routine and living environment.

Affective/Attitudes/Behavior
Adopts general risk perception attitudes.
Take action to minimize the risk of exposure to noise, especially frequency bands and sound levels considered harmful to human health.
Interacts with the community by arguing and debating measures to reduce risks associated with noise exposure.

Affective, Attitudes and Behavior - outcome evaluation:
It believes that civic-minded and noise-conscious behavior is key to minimizing the loss of quality of life in the local community.
It considers that individual behavior influences the regulation of noise levels and, therefore, the risk of noise pollution with consequent loss of quality of life at the community level.
Considers noise pollution to be an environmental determinant of health.
Adopt a healthy lifestyle in relation to noise exposure (e.g. reduce sound from personal equipment such as TV or PC).
It is committed to communicating and addressing community problems and challenges related to the effects of noise pollution and loss of quality of life.
Adopt a conscious attitude within the dwelling so as not to harm the noise environment of the neighborhood (for example: be careful with closing doors, talking loudly, among others, in the night period, when people are sleeping).

Learning objectives and outcomes
Uses computational tools to plot tables, graphs and other data that allow sound measurement and noise characterization.
Obtains, evaluates, and communicates scientific data and facts on the impacts of noise pollution on wildlife and human health.
Uses facts to build arguments about the health impacts of noise on the community.
Gives examples of sources of noise pollution that affect community health and quality of life.
It describes different strategies to protect, develop and influence community health.

Assessment methods

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Outcome assessment
Quantitative - paper questionnaire.
Qualitative - students' project.

Process evaluation - evaluation of the teaching-learning sequence - observation grid: target audience reach and extension; implementation of the scenario as planned; execution of the learning scenario as expected/organizational issues to be solved; duration of the teaching-learning sequence; number of people exposed; evaluation by level of involvement in the project - learners ("Was it fun to do the project?"/Do you think it would be fun to do the project again?")/"How do you think the project could be improved?").

Content
STEM content
Sound and Wave.
Vibration.
Frequency.
Breadth.
Period.
Wavelength.
Timbre.
Decibels.

Non-STEM content
Living conditions, urbanization, lifestyles.

Digital Learning Objects (LOs) and Digital Learning Resources (DERs)
New:
Online tool that allows the creation and interpretation of a spectral density plot. **(LO1)**
Noise (infographic). **(DER1)**
Worksheets **(RSP2)**
Sounds, noise levels and noise exposure (infographic). **(DER3)**
Public health consequences of noise (infographic). **(DER4)**
Strategies to reduce noise (infographic). **(DER5)**

Available resources (link)
https://www.dropbox.com/sh/n6mj1r903gw3ngf/AAASwRERfcVj9N1-H6IMp7Jva?dl=0

From other high quality sources/platforms:

- On the Physical Variables of sound and noise
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)

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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)**
https://www.rockwool.com/group/advice-and-inspiration/blog/the-cost-of-noise-pollution/ **(DER46)**

-Noise **pollution**: sources, prevention measures
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)

- Ways to Measure Noise and Sound
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)

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 101006468.

https://www.sciencelearn.org.nz/resources/573-measuring-sound (DER35)
https://www.schoolnet.org.za/PILAfrica/en/webs/19537/physics4.html (DER36)
https://youtu.be/fw78Vjk-Qig (DER37)
https://apps.apple.com/pt/app/decibel%C3%ADmetro-pro/id1227650795 **(DER37-Apple Store)**
Decibelimeter Pro - Apps on Google Play**(DER37-Google Play Store)**
https://www.vernier.com/files/manuals/slm-bta/slm-bta.pdf (DER38)
Noise Measurement - The Health Effects of Environmental Noise | Gouvernement du Québec (quebec.ca) (DER39)

Teaching-learning activities (lesson plan/learning process)
Target Discipline:
Physical chemistry lessons (Physics strand)
8th grade (pupils +/- 14 years)
About 6 lessons of 40-45 minutes
Physics teachers integrate other colleagues in the implementation of the scenario (e.g. ICT, science, mathematics and English teachers), as the implementation of the scenario is intended to be interdisciplinary.

Topics of each lesson:
Lesson 1: Sound and Noise.
Lesson 2: Noise pollution: sources, types of exposure, impacts.
Lesson 3: Physics concepts related to sound and wave. Practical activity of sound measurements.
Lesson 4: Analyze Noise case studies with emphasis on Noise Pollution, Neighborhood Noise and Workplace Noise.
Lesson 5: Identify measures and behaviors to adopt to reduce noise generation.
Class 6: Noise, individual behavior, quality of life.

Lesson 1: Sound and Noise
The main objectives to achieve in this lesson, from the learner's perspective, are:
Distinguish between the concepts of sound and noise.
Refers to the public health impacts of regular noise exposure.
Research, discuss and communicate facts about the consequences of noise exposure for wildlife and human health.

Lesson Summary 1:
Lesson 1 explores the physical parameters that characterize sound and noise, as well as the respective concepts, addressing concepts such as wave, timbre, frequency, period, wavelength, among others. In this lesson it is also intended that students identify noise sources in general, particularizing for environmental noise, neighborhood noise and occupational noise, and their sources and consequences for public health.

Activity 1
The teacher should start the lesson by describing the plan for the next lessons, which are directly related to a school research project. The following topics should be mentioned by the teacher:

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Students study and analyze problems related to noise exposure through a research work of scientifically based information on the subject (concept of noise, standards, recommended limits, sources of noise pollution, how to measure, among others).
Students analyze and describe different noise sources and identify the most harmful ones for human health by researching scientifically based data and information.
Students discuss in a classroom environment the main causes and consequences of noise at different levels (e.g. wildlife, environment, health).
Students analyse and discuss real cases of different types of noise by recording sounds using an audio recording application and by recording measurements of noise levels in decibel in their school with an acoustic meter, and then characterize the recorded noise in terms of the level of impact on public health.
Learners find solutions to mitigate the problems identified, based on the research and practical activities carried out in the previous activities, considering the consequences of noise for public health.
Students present the results of the school research project (facts, proposals and recommendations to the community at the open school event).

Activity 2

In lesson 1, the concepts of the scientific domain of Physics "Sound and Noise" are explored. The teacher describes the main sources of noise through a *brainstorming* activity in the classroom on the topic. The questions to ask in the *brainstorming activity* could be:
"What is sound? What about noise?",
"What are the sources of noise in a city?",
"What are the effects of noise? Does noise have any impact on human well-being and health?", "Are there impacts of noise on wildlife?
"What is the difference between sound and noise?",
"What are the parameters that researchers and professionals working in the field of physics use to characterize sound?".
"First fill in the blank space that identifies the type of graph being analyzed, and then fill in the other spaces with the names of the parameters that allow you to read the results observed in the graph."

Initially, and to facilitate both the organization of students' ideas and their research, they will be given a worksheet **[DER2]** where there is a field where students indicate their initial answers. These answers allow the teacher to qualitatively assess the students' initial conceptions about the process of the topic in question. The worksheet has another field where students should answer the same questions, but with the information they found during the research process. Students answer the questions individually and then form groups (3/4 students) to discuss their answers and their reasoning. The worksheet also has a standard image of a noise spectral density graph for students to identify all the parameters that are read from the graph. An example of the worksheet to be distributed to the students/group in this activity is seen in the images below.

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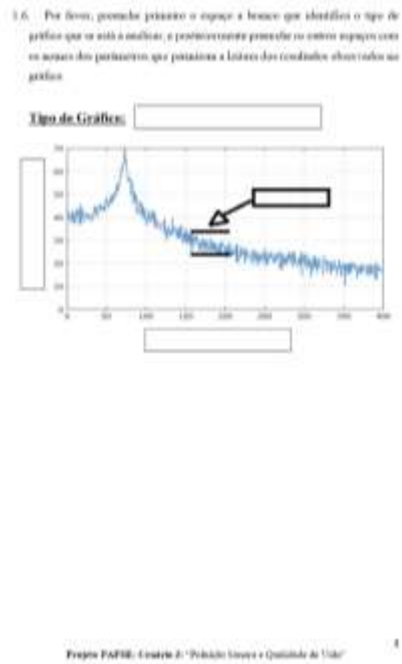
Unidade Curricular:
Docente:
Ficha de Trabalho N.º 1: Som e Ruído
Nome:
Data:
1.1. O que é o ruído?
1.2. Quais são as causas do ruído?
1.4. Qual é a diferença entre som e ruído?



The pupils write down their initial ideas and the teacher asks them to search for the information themselves by looking at reliable sources of information. Their reasoning is then discussed in groups (3/4). The teacher tells the pupils that they should always check the following criteria before taking information as valid:
The source and author of the information.
The date it was published, as the older a document is, the higher the risk of the information being out of date.
In addition, the teacher encourages learners to search for information in reliable databases (e.g. WHO database) and scientific articles, so that these two conditions are guaranteed. During the activity, the teacher circulates around the classroom, and checks if the students are having any difficulties in searching and processing information. If this happens, the teacher should provide students with the necessary support elements, and can structure the supporting information on the topic from the following resources:

sound | Properties, Types, & Facts | Britannica**(DER11)**
Know About The Difference Between Sound, Noise and Music (vedantu.com) **(DER12)**
Noise - Basic Information : OSH Answers (ccohs.ca) **(DER14)**
Noise Pollution: what it is, causes, effects and solutions - Iberdrola**(DER15)**
Noise Pollution | National Geographic Society **(DER16)**
Noise pollution health effects: Impact on mental and physical health (medicalnewstoday.com) https://www.cell.com/current-biology/pdf/S0960-9822(19)30863-2.pdf **(DER17)**

As mentioned, the worksheet has a figure with a spectral density graph of noise, where students identify the parameters that can be read from the diagram. Some images that serve as an example of what students observe in the graph, regarding its shape (wave type, amplitude, frequencies, among others), can be obtained in the following resources:

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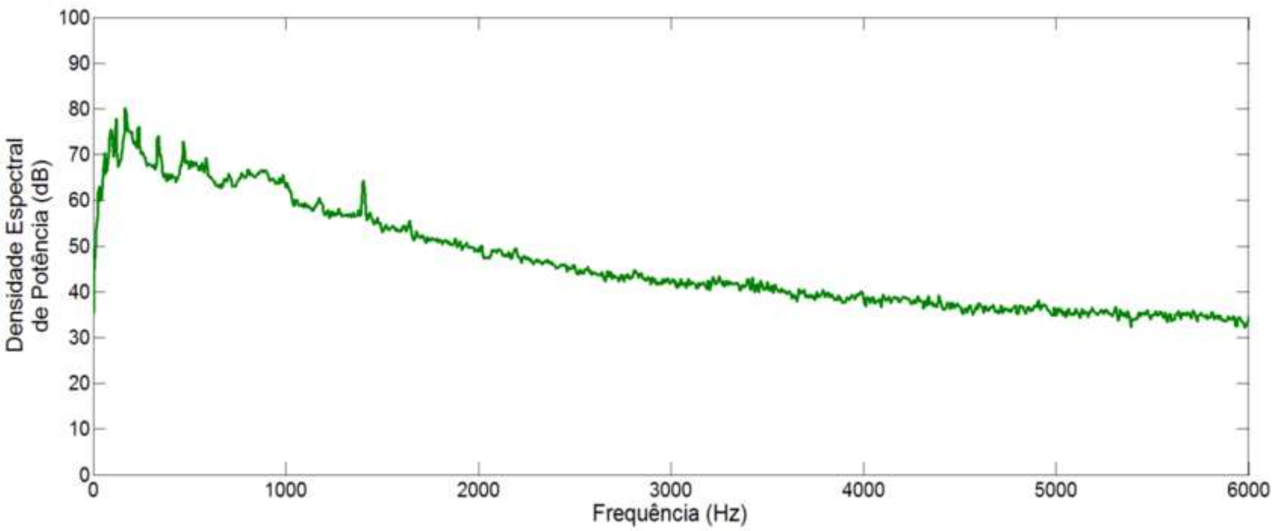
https://www.researchgate.net/figure/A-sinusoidal-sound-wave-showing-characteristics-of-wavelength-the-length-of-a-complete_fig2_320323376 (DER8)
Study Sound Wave Types, https://swphonetics.com/praat/tutorials/understanding-waveforms/ (DER9)
https://www.geeksforgeeks.org/speed-of-sound/ (DER10)

Activity 3

After the completion of the worksheet, and the internal discussion between the groups about their reasoning (with a time limit set by the teacher for the students to complete the worksheet and discuss their reasoning with their group), the teacher provides the students with credible, organized and systematized information on the topics to be investigated by the students (for this, the teacher prepares a presentation on the topic based on the sources mentioned in activity 2, **DER11, DER12, DER14-DER17).**

In this activity, the teacher also presents examples of noise spectral density graphs similar to the one students identified in activity 2, which they will analyze and discuss in subsequent lessons. An example of a noise spectral density graph can be seen in the image below. (**DER18** and **DER19**).



Activity 4

The teacher asks the students to fill in a simple questionnaire on the topics that have been covered in class. The following questions should be included: "1. Can noise be characterized as...? A) Any reproduced sound. B) Any unwanted/uncomfortable sound, considered unpleasant, with high levels or likely to disturb hearing. C) Sometimes a sound that we want to reproduce." 2. sound can be characterized by... A) Frequency only (in Hz); B) Sound Intensity only (in dB); C) Frequency (in Hz and Sound Intensity (in dB): ". 3. what is the main difference between sound and noise? A) There is no difference between sound and noise, both are the same. B) Sound is something pleasant to hear and noise is an unwanted sound. C) Noise is any sound that we want to reproduce; ". 4. continuous exposure to noise can cause...? A) A significant improvement in hearing abilities. B) An increase in people's concentration. C) Progressive loss of hearing abilities and loss of concentration in everyday situations."

Response:

B)

C)

B)

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C)

Students try to answer the questionnaire in groups (preferably in the groups previously formed to fill in the worksheet). During the activity, the teacher circulates around the classroom, supervising and supporting the students' work, asking questions, and providing *feedback* whenever necessary. The teacher notices whether the students have used credible sources of information and the difficulties they faced in obtaining the answers. To get more information on this last question, the teacher can also add the following question to the questionnaire: "What were the main difficulties you faced in the process of searching for information to answer the worksheet and/or questionnaire?".

Learning objects used in this lesson:
Worksheets **(DER2).**
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.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)

<u>Lesson 2: Noise: Impacts</u>
The main objectives to be achieved in this lesson, from the learner's perspective, are the following:
Can identify physical parameters that characterize noise.
Gives examples of noise sources that affect community health and quality of life.
Use facts to build arguments about the health impacts of noise in the community and in the workplace.
Analyzes scientific data to explain noise-related phenomena and produces argumentation on the topic.

Lesson Summary 2:
Lesson 2 increases students' knowledge of the public health impact of each noise source analyzed in the previous lesson, and how the severity of these sources can be assessed/quantified.
Activity 1
The sources of noise that should have been addressed in the worksheet for lesson 1 are:
Noise pollution due to traffic.
Noise pollution due to air traffic.
Noise pollution due to construction activities.
Noise pollution due to the sound caused by animals.
Noise pollution due to night activities (parties, discos, among others.).
Noise between different dwellings due to the activities of people and equipment.

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Noise in the workplace and workers' exposure to noise

The teacher explores the level of public health impact of each noise source, mentioning that to make this classification it is necessary to characterize the physical noise parameter based on other parameters such as sound levels, type of noise - broadband, tonal or impulsive, timbre or the phenomenon of sound wave propagation. A relationship should then be established between the level/quantification of these parameters and possible risks to public health and quality of life (e.g. long periods of exposure to high intensity noise can cause problems such as progressive hearing loss). Where possible, it should relate to existing legislation and regulations, namely, the General Noise Regulation (RGR) **(DER4).**
To address the topic, the teacher proposes a brainstorming activity in the class. It is suggested to launch the following questions:
"How can we quantify the severity level of the noise sources you identified in the previous sheet?"
"Do all sources of noise pollution have the same impact on people's health?"

In order to facilitate the organization of the students' thinking and the research they will carry out, the teacher distributes a worksheet **(DER2). On** this worksheet there is a field where the students write their initial ideas regarding the questions posed. The teacher then asks the students to search for credible information on the topic using reliable sources and to answer the questions again, this time in a second field of the worksheet. An example of the worksheet to be distributed to students/groups so that they can efficiently organize their reasoning and arguments can be seen in the images below.

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Cenário 3: "Poluição Sonora e Qualidade de Vida"

Unidade Curricular: ______________
Docente: ______________

Ficha de Trabalho N° 2.2: Poluição Sonora: Fontes, Tipos de Exposição e Impactos

Nome: ______________ Nº: ______

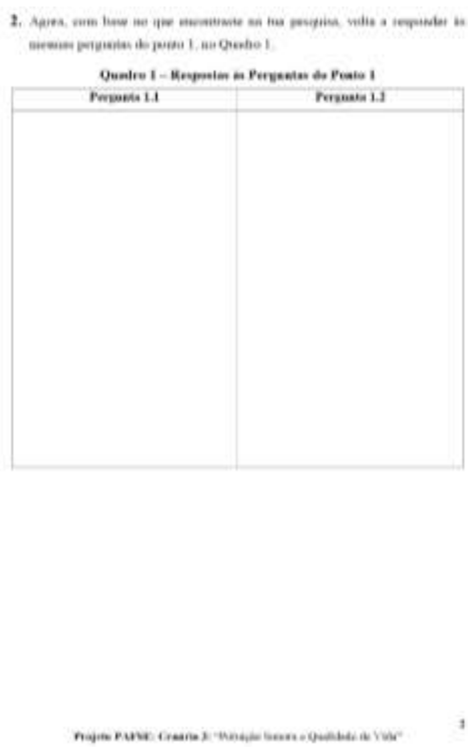
Data: ____/____/______

1. Com base no teu conhecimento, responde às seguintes questões:

1.1. Como é que podemos quantificar o nível de gravidade de cada uma das fontes de poluição sonora que identificaste na ficha anterior?

1.2. As fontes de poluição sonora têm todas o mesmo impacto na saúde das pessoas?

Projeto PAFSE: Cenário 3: "Poluição Sonora e Qualidade de Vida" 1


2. Agora, com base no que encontraste na tua pesquisa, volta a responder às mesmas perguntas do ponto 1, no Quadro 1.

Quadro 1 – Respostas às Perguntas do Ponto 1

Pergunta 1.1	Pergunta 1.2

Projeto PAFSE: Cenário 3: "Poluição Sonora e Qualidade de Vida" 1

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Students search for information independently in reliable sources of information and then discuss their reasoning in groups (3/4 students). The teacher then tells the pupils that they should always check the following criteria before taking information as valid:
The source and author of the information.
The date it was published, as the older a document is, the higher the risk of the information being out of date.
In addition, the teacher encourages students to search for information in reliable databases (e.g. WHO database), in scientific articles, so that these two conditions are guaranteed. During the activity, the teacher circulates around the classroom, and checks if the students are having any difficulties in searching and processing information. If this is happening, the teacher should provide the students with the necessary support elements, and can structure the supporting information on the topic 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.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)

Activity 2
After the completion of the worksheet, and the internal discussion between the groups about their reasoning (with a time limit set by the teacher for the students to complete the worksheet and discuss their reasoning with their group), the teacher provides the students with credible, organized and systematized information on the topics to be investigated by the students (for this, the teacher prepares a presentation on the topic based on the sources mentioned above, **DER11, DER12, DER15, DER23-DER30)**.

Task 1
Pupils are encouraged to research the impact noise has on their country and how the problem is being managed by the relevant government bodies. (**DER4, DER5**). Pupils are divided into the groups from previous lessons and asked to construct a PowerPoint presentation on the topic in question to be presented at the open school event (to be discussed later in lesson 6). Students should look for factual (official) information on how the problem is affecting the populations of their country. Once they have found this information, they should look for other information related to current legislation/public policies, among others, that are being implemented by their government to mitigate the effects of noise pollution. To help them carry out this task, they will be provided with a worksheet (**RSP2**). An example of the worksheet to be distributed to the learners/groups is seen in the images below.

Note: This task should be presented in the classroom, but should be carried out at home, in parallel with

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the implementation of the scenario, and the activities proposed for the task have to be completed by the end of the implementation of the scenario (i.e. by lesson 6).

PAFSE Partnerships for Science Education
ISEL

Cenário 3: "Poluição Sonora e Qualidade de Vida"

Unidade Curricular: ____________
Docente: ____________

Ficha de Trabalho Nº 3: Tarefa 1

Nome: ______________________ Nº ________

Data: ____/____/____

1. Tendo em conta o que já estudaste nas aulas anteriores, e a partir dos artigos que leste, realiza uma pequena pesquisa sobre o impacto que a poluição sonora tem no teu país, identificando as causas, as fontes e as consequências do problema. Deves procurar também normas, legislações, etc… que o teu país tem implementado atualmente, ou que tenciona implementar para prevenir/mitigar o problema em questão. Para te ajudar na realização da tarefa, nos Quadros 1 e 2 podes identificar os impactos da poluição sonora no teu país, e as medidas aplicadas pelo teu governo para combater o problema, respetivamente.

Quadro 1 – Impactos da Poluição Sonora no Teu País

Impactos

1

Projeto PAFSE: Cenário 3: "Poluição Sonora e Qualidade de Vida"

Quadro 2 – Legislação em Vigor no Teu País Para Combater o Problema

Legislação, Normas, etc…

2

Projeto PAFSE: Cenário 3: "Poluição Sonora e Qualidade de Vida"

Learning objects used in this lesson:
Facts on the existence of noise pollution **(DER1)**
Worksheets **(RSP2)**
Facts about public health consequences of noise. **(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://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)

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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)

Complementary Activity

In order to reinforce students' knowledge, as a complementary activity to those developed in classes 1 and 2, it is proposed that students refer again to the concept of noise, and that they identify the respective sources and the impact that noise can have on human health. For this purpose, the following sequence of activities is proposed:

Activity 1

Learners return to their groups and the teacher organizes a brainstorming activity on the topic in question. The questions to be asked to the pupils could be:
"Can you define what "noise" is?"
"Can you identify sources of noise? Can you give some examples?"
"How can noise affect people's health and lives?"

In order to facilitate the organization of the students' thinking and the research they will carry out, the teacher distributes a worksheet **(DER2). On** this worksheet there is a field where the students write their initial ideas regarding the questions posed. The teacher then asks the students to search for credible information on the topic using reliable sources and to answer the questions again, this time in a second field of the worksheet. An example of the worksheet to be distributed to students/groups so that they can efficiently organize their reasoning and arguments can be seen in the images below.

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2.7. NOVA University of Lisbon (UNL)

AMENDMENTS

Amendments of the revised version of the educational scenario entitled: *“The role of environment and animal health in zoonotic diseases and pandemics”*
The updates on this scenario primarily focused on improving the format, language, and visuals, offering a more engaging learning experience. Additionally, we included a comprehensive list of partners available for the STEM activity mentioned during the implementation of the scenario in classroom environment, since the previous version only mentioned a single partner and its possible activity- keep in mind that this partner no longer collaborates with us. The link leading to the LO changed (in the pilot version, it led us to Canvas, now it links to PowerPoint online).

Amendments of the revised version of the educational scenario entitled: *“Non-communicable diseases”*
Regarding the revised version of the scenario on “Non-Communicable Diseases (NCDs)”, throughout the review process, our team focused on optimizing the content to deliver an even more impactful and informative learning experience. Some amendments were made, primarily concerning the format of the PowerPoint presentations, and supporting materials, once again. Additionally, we did minor language corrections, ensuring greater clarity and cohesiveness throughout the document. In addition to the above improvements, we inform that we incorporated a comprehensive list of partners relevant to this scenario.

Amendments of the revised version of the educational scenario entitled: *“Sustainable Development Goals”*
During the review process, we focused on fine-tuning the content to ensure an even more engaging and informative learning experience. The amendments primarily consisted on the format of the PowerPoint presentations and accompanying materials. We made minor language corrections to enhance clarity and coherence throughout the document, as said previously regarding the other scenarios. Furthermore, we took special care to improve the layout of some pictures in the PowerPoint presentations, which resulted in adjustments to the links leading to the relevant resources. Once again, we also included a comprehensive list of partners relevant to this specific scenario.

Amendments of the revised version of the educational scenario entitled: *“Artificial Intelligence responses when clinical symptoms appear”*
Throughout the review process, some amendments were made to enhance the quality of the content. These included formatting improvements on the PowerPoint presentations and related materials, along with some language corrections to ensure clarity and accuracy.
Additionally, we made a few updates to the visuals in the PowerPoint presentations (because of some pictures presenting lower quality than that that we want to present, resulting in the need to change the links that direct users to view the relevant resources (in the main document attached to this email). Rest assured, these changes were implemented to provide a seamless and engaging learning experience for our audience.
Furthermore, we incorporated a list of partners relevant to this specific scenario.

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2.7.1. The role of environment and animal health in zoonotic diseases and pandemics

Main partner responsible
UNL (ENSP-NOVA)

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.

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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

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 one to lesson five students work alone or occasionally in groups.
From lesson six to lesson twelve students form four- or five-member groups which conduct 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 act 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

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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.

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

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"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.
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.
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.

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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 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, which can spread to humans through direct contact or through food, water, or the environment.

Pedagogical glossary

Brainstorming. Brainstorming is an instructional technique with several variations, that might take place within small groups 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 of 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 participation 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 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.

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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.
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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CDC (USA) - One Health Office Fact Sheet - Connecting human, animal, and environmental health - https://www.cdc.gov/onehealth/pdfs/OneHealth-FactSheet-FINAL.pdf
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(WHO) - Taking a multisectoral, one health approach: a tripartite guide to addressing zoonotic diseases in countries - https://www.who.int/publications/i/item/9789241514934.

Competences / Learning Goals

Key Competences

STEM / Personal, social and learning to learn, literacy, citizenship

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

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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:
Recognizes and characterizes the environmental factors that affect human and animal health.
Identifies the disruptive changes in animal health that influence the emergence of zoonotic diseases.
Identifies the most important characteristics of pandemics.
Identifies measures and proposes general action to mitigate and adapt to climate change.
Identifies relevant changes of climate change and identifies suitable indicators to monitor the changes.
Identifies the environmental determinants of health and understands their relationship with climate change and SDGs.
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:
Selects appropriate concepts, indicators, and evidence to characterize environmental changes that can cause harm to human and animal health.
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.
Can adopt mitigation measures (e.g., using public transportation instead of private car).

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Can propose concrete action towards mitigation of environment degradation in their/others routine.
Feels able to influence the adoption of environment degradation mitigation measures by others (e.g., family, peers, friends).
Selects appropriate sources to characterize climate change and other environmental changes impacting human and animal health from a scientific perspective.
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 environmental degradation on human and animal health.
Adopting attitudes supporting sustainable development, urban and environmental health challenges.
Engaging in public speaking and debating of measures to mitigate environmental degradation.

Attitudes and behavior - outcome assessment:
Believes that environmental degradation is a relevant factor in the emergence of pandemics.
Believes that scenarios such as climate change influence the incidence of zoonotic diseases.
Believes that is important to adopt measures to prevent environmental degradation.
Reproves patterns disregarding climate change in our communities.
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 the 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.
Give 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.

Assessment methods
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

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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

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 (DLOs) and Digital Educational Resources (DERs)

EN : Lessons_EN2023.pptx
PT: Aulas2023_PT.pptx

New:
Hidden treasure game with post-its [LO1]
Environmental determinants of health [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]
Zoonotic diseases [DER6]
One health [DER7]
Data from surveillance systems for zoonotic diseases [DER8]
Concepts related with climate change (cards game) [LO2]
What is climate change? [DER9]
How does climate change impact health? [DER10]
Decarbonization and health [DER11]
Zoonotic diseases and pandemics [DER12]
From epidemics to pandemics [DER13]
Anthropogenic activities and pandemics [DER14]
Cards with mortality data from pandemics [LO3]
Questionnaire – quantitative assessment [DER15]
Template for students to design the infographics (*canva file*) [DER16]
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]

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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]

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 the environment has an influence on your health?

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Do you consider that the environment has an influence on 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 climate change affect humans' health?

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 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 takes as a starting point the answers obtained during the icebreaker moment for questions related to 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.,

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malaria), zoonotic influenza, brucellosis, salmonellosis, monkeypox. 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 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 to 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 takes 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

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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]
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 from 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]

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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]

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
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 to better public health.
b) identifying actions to fight NCDs in their community. for better expectancy and quality of life for all.

Visits to organizations interested in STEM and public health education:
INSA (national public health laboratory - department of non-communicable diseases)
https://www.insa.min-saude.pt/

FCT NOVA (visit to laboratories)
https://www.fct.unl.pt/

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Sporting Clube Portugal (visit to stadium or Cristiano Ronaldo Academy)
https://www.sporting.pt/

Auchan Portugal (visit of a nutritionist to the school with an activity on food and the environment)
https://www.auchan.pt/

Holon Farmacies (various activities on nutrition, pharmacology and health)
https://www.farmaciasholon.pt/

Águas de Portugal (Waters of Portugal - Environmental Education Center Water at 360º)
https://www.adp.pt/pt/comunicacao/agua-a-360%C2%BA/?id=197

SILab (visit to the Social Innovation Laboratory of Instituto Superior Técnico – University of Lisbon)
http://silab.tecnico.ulisboa.pt/

ATEC – Training Center – visit to the Academy to present professional training of a technical nature
https://www.atec.pt/

Escola Nacional de Saúde Pública (https://www.ensp.unl.pt/) – activity on STEM myths and professions with challenges on SDG 3 (in relation to others) and guests from various areas and from other institutions such as Chaperone (https://chaperone.online) and ICNOVA (https://www.icnova.fcsh.unl.pt/en/homepage-2/)

(The list of partnerships will continue to be updated until the end of the project. You can consult all our partnerships here: https://pafse.eu/pt/partes-interessadas-pafse/)

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

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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.

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:
What is climate change?
What are environmental determinants of health?
What do animal health and human health have in common?
What is a zoonotic disease?
How does animal health affect the emergence of pandemics?
What can we do at our community level to prevent climate change and pandemics?
What is your workplace/school doing to fight climate change?
What can we do to minimize our impact on the environment?
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

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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:
Students will be able to incorporate evidence in their infographic coming from reputable data sources to support their ideas and show media literacy.
Students will be able to communicate the merits and limitations of various data and information sources considered in the work process.
Students will be able to identify and communicate environmental factors that contribute to climate change in their community.
Students will be able to identify and communicate evidence-based policy measures to prevent and mitigate climate change effects in communities.
Students will be able to use scientific argumentation to justify policy choices.

Teaching-learning process for school project (summary):
Collection of evidence (data, articles, pictures).
Evaluation of the evidence based on criteria and selection of the relevant and non-biased information.
Identify effective presentation formats.
Produce the infographics.
Present the infographic in open schooling event.

Organization of the open schooling event:
Each project output (infographic) is presented by the students in a community setting (e.g., exposition center, garden, museum, science fair).
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.
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, managers).

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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	
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 the 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:** 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 to climate change? A) SDG 7, 12, 13, 14, 15. B) SDG 13. C) SDG 14 and 15.
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.

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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: Health care systems overloaded, inadequate medical supplies, economic and social disruption. Travelling prohibited, food scarcity, jobs losses. C) Educational institutions closed, gymnasiums closed, cultural activities stopped.
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.
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.
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 the use of private cars. 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 is still

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	working C) Use air conditioning always in the maximum level.
SKILLS	
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.
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.
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
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 environmental degradation. 1) Strongly Agree 2) Agree

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	3) Undecided 4) Disagree 5) Strongly Disagree
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
Selects appropriate sources to characterize climate change and other environmental changes impacting human and animal health from a scientific perspective.	**Question 6.1** To find scientific information about 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.
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

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	3) Undecided 4) Disagree 5) Strongly Disagree
Beliefs, attitudes, and behavior There are no correct or incorrect answers; we are only interested in knowing your perspective.	
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
2. Believes that scenarios such as climate change influence the incidence of zoonotic diseases.	**Question 2.1** 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** Climate change influences the incidence of zoonotic diseases. 1) Strongly Agree

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	2) Agree 3) Undecided 4) Disagree 5) Strongly Disagree **Question 2.3.** The mitigation of climate change effects may have an important contribution for the prevention of zoonotic diseases. 1) Strongly Agree 2) Agree 3) Undecided 4) Disagree 5) Strongly Disagree
3. 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

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	of using a 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.
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
Is committed to communicate and address the problems and challenges of the community in relation to the environmental determinants of health and to	**Question 5.1** I will try to communicate the problems related to the influence of the environment on human health within my community. 1) Strongly Agree 2) Agree 3) Undecided 4) Disagree 5) Strongly Disagree

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contribute to the SDGs.	**Question 5.2** I will try to address the challenges posed by 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 make efforts to achieve the SDGs. 1) Strongly Agree 2) Agree 3) Undecided 4) Disagree 5) Strongly Disagree **Question 5.6** I know that a contribution for the attainment of each SDG is a contribution 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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2.7.2. Individual and socioenvironmental influences on humans' health and the burden of non-communicable diseases

Main Partner responsible
UNL (School of Public Health)

<u>Context</u>
The educational system has a vital 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 a 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.

<u>Scientific content and its relevance to public health education</u>
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

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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. Fortunately, science curriculums at various 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 one to lesson five 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 six to lesson twelve students form four- or five-member groups which conduct 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

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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 on values of intellect, critical thinking goes beyond subject/matter division.

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

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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.

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

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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.
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 using 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

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within small groups 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 of 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 participation 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 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

Pizzi, M, and Vroman, K (2013). "Childhood obesity: effects on children's participation, mental health, and psychosocial development." Occup Ther Health Care, 27: 99-112.

Gunawardena, N, et al. (2016). "School-based intervention to enable school children to act as change agents on weight, physical activity, and diet of their mothers: a cluster randomized. controlled trial." International Journal of Behavioural Nutrition and Physical Activity, 13:45.

Fornari, L, et al. (2013). "Children First Study: how an educational program in cardiovascular prevention at school can improve parents' cardiovascular risk." Eur J Prev Cardiol, 20: 301–9.

He, F, et al. (2015). "School based education programme to reduce salt intake in children and their

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Miller, A, Lee, H, and Lumeng, J (2015). “Obesity-associated biomarkers and executive function in children.” Pediatr Res, 77: 143-7
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 to 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 their determinants.
Knowledge - outcome assessment:
Recognizes and characterizes the major NCDs.
Identifies the most important risk factors for each NCD.
Identifies measures and proposes general action to fight NCDs.
Defines burden of disease and identifies indicators to measure it.
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.
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.

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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 get access to the relevant resources.

Skills – outcome assessment:
Selects concepts, indicators, and evidence to characterize disease burden.
Can anticipate the consequences of unhealthy lifestyles.
Can adopt a healthy lifestyle.
Feels able to propose concrete action towards adopting healthy lifestyles in his/her routine.
Feels able to influence the adoption of healthy lifestyles by others (e.g., family, peers, friends).
Selects appropriate sources to characterize NCDs from a scientific perspective.
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 in 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:
Believes that health is a fundamental component of quality of life.
Believes that lifestyles influence the incidence of NCDs.
Believes that is important to adopt a healthy lifestyle to prevent NCDs and stay healthy.
Reproves patterns of risky and unhealthy behavior in his/her living environment.
Adopts a healthy lifestyle.
Is committed to communicating and addressing the problems and challenges of the community in relation to the determinants of health and to contribute to the SDGs.
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 the 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>
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.

<u>Digital Learning Objects (DLOs) and Digital Educational Resources (DERs)</u>
<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 relates to 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*)

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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 scientific posters.
Primary prevention (*infographic*) [ER86-87]
Secondary prevention *(infographic)* [ER88]
Tertiary prevention (*infographic*) [ER89]

Available resources (link):
Session1 and 2:
https://www.canva.com/design/DAE1uXuidgU/xrIbZb3qQFNayVF6LNcKSQ/view?utm_content=DAE1uXuidgU&utm_campaign=designshare&utm_medium=link2&utm_source=sharebutton

Session 3:
https://www.canva.com/design/DAE8eFZ0_Jw/y3C8AmhA5bH1GYsDtWEt7A/view?utm_content=DAE8eFZ0_Jw&utm_campaign=designshare&utm_medium=link2&utm_source=sharebutton

Session 4 and 5:
https://www.canva.com/design/DAE8eYgMIVQ/VBiMXKzqbpf4HxNdysS9GA/view?utm_content=DAE8eYgMIVQ&utm_campaign=designshare&utm_medium=link2&utm_source=sharebutton

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]

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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 study Urban 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]
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]

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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
Principal target:
Science classes
9th 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.

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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 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).

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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 on 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:
Has the expectancy of life increased or decreased in the past 100 years?
Do people live longer or less today than they did at the beginning of the century? Why?
[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 trustworthy 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 to implement 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

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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 kilometers 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.

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 housing, 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

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vegetables are easily 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 the teacher explains that living conditions related to Agenda for Sustainable Development of the United Nations. These influences are more difficult, but not impossible, to change, as they ask for concerted action from 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 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 around 18 degrees,

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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 are rejected, due to their effects on the planet and consequences for 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 ecological 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.
Select appropriate sources to characterize the burden of diseases from 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 into 3

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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 – 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 the leading causes of deaths are, 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's 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.

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The following questions and sources of evidence may be used for this purpose:

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

Lesson 4: major non-communicable diseases

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

Identify and characterize the major NCDs.

Select appropriate sources to characterize NCDs from a scientific perspective.

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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.
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: ischemic heart disease and stroke. The following resources should be used at this stage: **cardiovascular diseases [ER54-55].**
The teacher explains the pathophysiology of **ischemic 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

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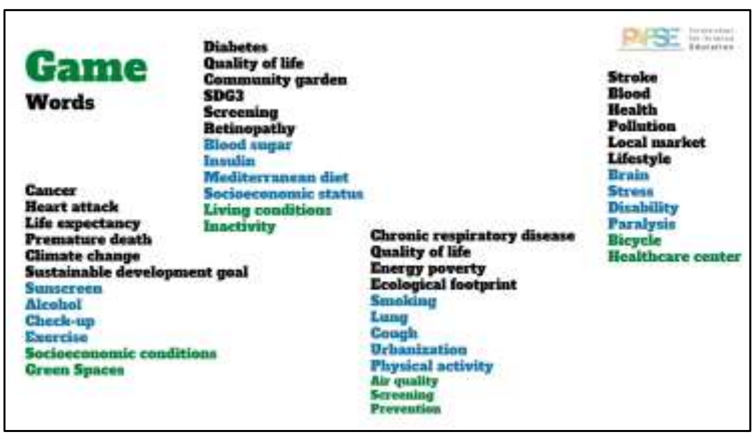
preventive action. The following resources should be used at this stage: **cancer [ER70-75]. After presenting ER 71, the teacher asks students to identify the most common organ affected by cancer. After presenting [ER 73] the teacher asks students to identify two symptoms of cancer.**

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].**

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 to 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 into 2 groups. In 5 minutes, they should propose at least five 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 tertiary prevention to limit the complications of the disease. The following resources should be used at this stage: **tertiary prevention [ER89].**

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Assessment task 1: build a systems map (qualitative assessment)
The availability of a 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.

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 to better public health.
b) identifying actions to fight NCDs in their community. for better expectancy and quality of life for all.

Visits to organizations interested in STEM and public health education:
INSA (national public health laboratory - department of non-communicable diseases)
https://www.insa.min-saude.pt/

FCT NOVA (visit to laboratories)
https://www.fct.unl.pt/

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Sporting Clube Portugal (visit to stadium or Cristiano Ronaldo Academy)
https://www.sporting.pt/

Auchan Portugal (visit of a nutritionist to the school with an activity on food and the environment)
https://www.auchan.pt/

Holon Farmacies (various activities on nutrition, pharmacology and health)
https://www.farmaciasholon.pt/

Águas de Portugal (Waters of Portugal - Environmental Education Center Water at 360º)
https://www.adp.pt/pt/comunicacao/agua-a-360%C2%BA/?id=197

SILab (visit to the Social Innovation Laboratory of Instituto Superior Técnico – University of Lisbon)
http://silab.tecnico.ulisboa.pt/

ATEC – Training Center – visit to the Academy to present professional training of a technical nature
https://www.atec.pt/

Escola Nacional de Saúde Pública (https://www.ensp.unl.pt/) – activity on STEM myths and professions with challenges on SDG 3 (in relation to others) and guests from various areas and from other institutions such as Chaperone (https://chaperone.online) and ICNOVA (https://www.icnova.fcsh.unl.pt/en/homepage-2/)

(The list of partnerships will continue to be updated until the end of the project. You can consult all our partnerships here: https://pafse.eu/pt/partes-interessadas-pafse/)

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?

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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 five 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:
Accessibility, transportation options and security
Public green and social spaces
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?

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Are bus stops and stations in convenient places?
Is public transport safe and easy to access, whatever people's age or mobility?
Are there many cars on the roads surrounding the school?
Is there too much traffic surrounding the 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 down?
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 in 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?
Are there any recreative events like art displays and performances occurring to celebrate local artists and cultures?
Are there any natural features in 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 or initiative ongoing about the design of public space?
Is there any discussion or initiative ongoing about planting trees?
Is there any discussion or initiative ongoing about water saving?
Is there any discussion or initiative ongoing about energy saving?

School environment (Group 3)

Are there facilities to park a 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?

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Is there any strategy ongoing to save energy?
Is there any strategy ongoing to avoid waste of water?
During meals at school is usual to throw away food?
Is there any strategy ongoing to avoid food waste?
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

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.

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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.

<u>Session 3: data analysis</u>
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.

<u>Session 4-5: presentation of evidence</u>
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.

<u>Session 6: open schooling event</u>
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 but also social and environmental factors. They also get high-level understanding on strategies to minimize

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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:
Watch this video.
Lisbon case study Urban environment and health, 2017 - YouTube
Take a look at these infographics and texts!
Healthy places
Placemaking guidelines and initiatives
Perform this assessment.
Place Standard

Teaching-learning process for school project (summary):
Collection of evidence.
Evaluation of the evidence based on criteria and selection of the relevant and non-biased information.
Identify effective presentation formats.
Produce the output (e.g.: scientific poster**)**
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 behaviours 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

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Knowledge	
1. Recognizes and characterizes the major NCDs.	**Question 1.1:** What are the main 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. **Question 1.2:** What are the most frequent symptoms of heart attack? A) chest pain, light-headedness, breathlessness. B) blurred vision, confusion, paralysis of one side of the body. C), light-headedness, breathlessness, cough. **Question 1.3:** What are the most frequent symptoms of cancer? A) fever, fatigue, weight loss B) blurred vision, paralysis of one side of the body. C), light-headedness, cough, increased appetite. **Question 1.4:** What are the most frequent symptoms of a 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:** What are 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:** What are the main risk factors for ischemic heart disease? A) pollution, smoking, alcohol consumption, fatty diet. B) exposition to dusts and chemicals at work, inactivity, diet rich in vegetables. C) Exposition to ultraviolet radiation, exposition to solid fuels, chronic infections. **Question 2.2:** What are the main 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:** What are the main 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	**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.

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NCDs.	B) adopt a meat-free diet, consume food supplements and practice exercise. C) avoid the sun and plant-based foods, drink soda and use 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 the 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 the 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 from an economic perspective. C) the impact of the problem from 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.
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 to characterize the burden of diabetes. Which indicator would you select? A) number of deaths/100.000 people. B) number of citizens with the disease. C) premature mortality and years lived with poor health.

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2. Can anticipate the consequences of unhealthy lifestyles and risky behavior (e.g., smoking).	**Question 2.1:** Urbanization, pollution, smoking, alcohol consumption, diet full of fat and inactivity are risk factors for non-communicable diseases. Considering that factors that elevate disease risk accumulate gradually over the life course, identify the most important consequences of having these conditions present in your lifestyle: A) Abdominal fat, overweight, hypertension. B) Mental disease, hypertension, underweight. 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 acting 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, 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 healthy 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 my home environment which promote a healthy lifestyle: 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 from a scientific perspective.	**Question 6.1:** I believe that to find valid information, based on science, about health and diseases, I should consult the following sources: A) scientists, scientific publications, WHO webpages and databases. B) newspapers, google, YouTube. C) friends, journalists, social media.
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 lifestyle that benefits health and 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.

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	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 (for example, fish, vegetables, fruits) influences the incidence of non-communicable diseases (e.g.: cancer, cardiovascular diseases): 1) strongly disagree… 5) strongly agree. **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 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 risky 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.

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	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 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 that possibility. 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. 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 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.

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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

2.7.3. 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

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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 three for the students to explore the learning objects. From lesson six 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.

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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 humans, 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.

Pedagogical glossary

Brainstorming. Brainstorming is an instructional technique with several variations, that might take place within small groups 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 of 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 participation 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 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/
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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

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:
Explains the history of the development of SDGs.
Recognizes the importance of the SDGs.
Characterizes the goals and defines relevant concepts regarding the SDGs.
Identifies quantitative measures to track the progress of the SDGs.
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:
Selects appropriate sources to characterize performance on the SDGs.
Proposes concrete actions towards promoting sustainability in his/her lifestyle.
Influences the adoption of choices aligned to the SDGs by others (e.g., family, peers, friends).

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Is able to demonstrate values and to adopt individual attitudes that lead to more sustainable societies.
Selects appropriate scientific data and information to describe the progress of the SDGs.
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:
Believes that is important to contribute to the Global Goals.
Believes that working on the Global Goals can lead to positive outcomes at the community level.
Believes that it is crucial to identify obstacles and problems faced by communities regarding the SDGs.
Believes that efforts must be employed to achieve the SDGs.
Is committed to adopting sustainable behaviors in his/her lifestyle.
Is committed to communicate and address the problems and challenges of the community in relation to sustainable development.

<u>Learning goals and outcomes</u>
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 advance the SDGs.
Finds evidence, compilates data and information to help progress the SDGs at the local level.
Uses evidence to propose measures that contribute to the sustainability agenda at the community level and communicates them to the community leadership.
<u>Assessment methods</u>
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)

<u>Content</u>
STEM content (relevant to learning goals & research topics)

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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 (DLOs) and Digital Educational Resources (DERs)
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]**
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-

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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)
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 on 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

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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_flZBekxOUFRlSGpDUWs2QmlOa1JyMmJHTjlTWENpclINM2lIV09rRU9haUk?resourcekey=0-vvNBnQK5OOYy4VSMseF3Xg

Digital learning objects

Lesson1:
https://www.canva.com/design/DAFOWc8pm9Y/CK6thJOGq3W-N12qYpMxuw/view?utm_content=DAFOWc8pm9Y&utm_campaign=designshare&utm_medium=link&utm_source=publishsharelink

Lesson 2 :
https://www.canva.com/design/DAFOWWNthYs/hhF7zD1RvGJf5G_wLA_2_g/view?utm_content=DAFOWWNthYs&utm_campaign=designshare&utm_medium=link&utm_source=publishsharelink

Lesson 3 :
https://www.canva.com/design/DAFR7gE3woo/x4M0GCX-QA0CqT_ZvbaMMw/view?utm_content=DAFR7gE3woo&utm_campaign=designshare&utm_medium=link&utm_source=publishsharelink

Lesson 4 :
https://www.canva.com/design/DAFR7liGYsk/L6Vfl0WALLaOyG7DhrwmQA/view?utm_content=DAFR7liGYsk&utm_campaign=designshare&utm_medium=link&utm_source=publishsharelink

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
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 into groups for discussion, and each group must come up with a

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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 explores 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 the 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.

<u>Lesson 2: Individual actions towards the SDGs</u>
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.

Discussion on possible actions, of individual nature, that 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 is not used anymore; being vocal about inequality; to name a few. The discussion of actions will be supported by the following resource:

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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's 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: 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 depends 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 shortcomings (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.
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

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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 wastewater 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 shortcomings (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]**

Lesson 4: COVID-19 and SDGs

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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 to answer 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 or 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.

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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 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:

Discussion with school representatives. The school is a transformative environment, and the representatives can discuss with students how sustainable development is promoted in the school setting. Students can identify actions and interventions promoted at the school level that may contribute to the SDGs.

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.

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 teleconferences, classroom visits by experts, or student visiting organizations. The **visits to organizations interested in STEM and public health education** may include the following entities**:**

INSA (national public health laboratory - department of non-communicable diseases)
https://www.insa.min-saude.pt/

FCT NOVA (visit to laboratories)
https://www.fct.unl.pt/

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Sporting Clube Portugal (visit to stadium or Cristiano Ronaldo Academy)
https://www.sporting.pt/

Auchan Portugal (visit of a nutritionist to the school with an activity on food and the environment)
https://www.auchan.pt/
Holon Farmacies (various activities on nutrition, pharmacology and health)
https://www.farmaciasholon.pt/

Águas de Portugal (Waters of Portugal - Environmental Education Center Water at 360º)
https://www.adp.pt/pt/comunicacao/agua-a-360%C2%BA/?id=197

SILab (visit to the Social Innovation Laboratory of Instituto Superior Técnico – University of Lisbon)
http://silab.tecnico.ulisboa.pt/
ATEC – Training Center – visit to the Academy to present professional training of a technical nature
https://www.atec.pt/

Escola Nacional de Saúde Pública (https://www.ensp.unl.pt/) – activity on STEM myths and professions with challenges on SDG 3 (in relation to others) and guests from various areas and from other institutions such as Chaperone (https://chaperone.online) and ICNOVA (https://www.icnova.fcsh.unl.pt/en/homepage-2/)

(The list of partnerships will continue to be updated until the end of the project. You can consult all our partnerships here: https://pafse.eu/pt/partes-interessadas-pafse/)

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 open to 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.

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Relevance. The agenda for Sustainable Development 2030 brings attention to the main challenges our world faces in various 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, which contribute the sustainability agenda, while promoting equality, health, well-being, and sustainability in their community.

Estimated duration. The school research project starts after lesson five 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 human 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 advance 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 in the school community that don't contribute to the UN Agenda for Sustainable Development?
Students are separated into 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:
Social progress (SDG1, SDG2, SDG3, SDG8, SDG10, SDG11)
Environmental protection (SDG 3, SDG6, SDG7, SDG 11, SDG 12, SDG13, SDG 14, SDG 15)
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 questionnaire and 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 how these attributes in their school/community

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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
3, 11, 13	Is the school accessible by bicycle?	Survey
3, 11, 13	Is the 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

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		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).

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
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).

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In summary, a problem statement and a starting question are defined as a way 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)

3. Investigation- 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.
4. Conclusion- –analyzing the collected evidence:
Students analyse the data collected and draw conclusions. The teacher discusses with the students the obtained results and 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.
5. Discussion – 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 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).

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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 as 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:
Students are able to incorporate evidence in their scientific posters coming from reliable data sources to support their ideas and show media literacy.
Students are able to identify and communicate measures based on the data collected by them to help progress the SDGs and produce positive impacts in the school and community settings.
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.

Students, parents, school community and relevant local stakeholders attend the event and understand how the progress regarding the SDGs is associated with positive outcomes for the community health and

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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.

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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.
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 for 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 with 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

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	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 be 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 achieve 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 achieve the SDGs by others (family, friends). 1) definitely true... 5) definitively false.
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.

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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 Global Goals have. *1) No influence... 5) Complete influence* over the most important challenges that my community faces.

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	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 possible to identify obstacles and problems that the 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.
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 to 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 a 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

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	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.
7. Attitude Toward SDGs.	**Question 7.1:** For me to achieve SDGs is: harmful :_____:_____:_____:_____:_____: beneficial pleasant :_____:_____:_____:_____:_____: unpleasant good :_____:_____:_____:_____:_____: bad worthless :_____:_____:_____:_____:_____: valuable enjoyable :_____:_____:_____:_____:_____: unenjoyable

2.7.4. Artificial Intelligence responses when clinical symptoms appear

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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 have been attributed to COVID-19 around the globe. Creating awareness of the symptoms and actions to be taken in their presence is very important, not only to increase personal protection but also to help contain 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 established 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 one to lesson two 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 conduct the school project. The use of computer is required.

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

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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.
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 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 groups 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 of 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 participation and their collaboration and communication skills.
Data – Any collection of information converted into a digital form**.**
Information. Facts, ideas, concepts, and data that have been recorded, analyzed, and organized in a way

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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 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:

Defines relevant concepts of artificial intelligence.

Recognizes the limits of AI.

Recognizes the importance of AI in Healthcare

Characterizes Intelligence Interfaces

Characterize chatbots and understand their role in the healthcare sector.

Skills (abilities/competences)

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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:
Selects appropriate sources to characterize AI systems from a STEM perspective.
Selects appropriate techniques and methods to develop a simple AI System.
Can develop a simple AI system to fight epidemic outbreaks.
Can propose concrete AI-based software development actions to fight epidemic outbreaks.
Can anticipate the consequences of inappropriate use of AI systems in epidemic outbreaks.

Affective /Attitudes/Behaviour (*beliefs)*
General:
Intellectual curiosity (simulators are adequate for 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 other 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 in public speaking and debating of measures to boost the use of AI in public. health, particularly in the emergence of epidemic outbreaks.
Engaging in public speaking and debating 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:
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 collaborative work is critical to overcome obstacles and problems.
Believes that efforts should be made to have the best technologies in healthcare.
Considers that respect for the plurality of points of view is crucial to obtain good and lasting solutions.
Attitudes towards AI

<u>Learning goals and outcomes</u>
Applies appropriate methods and techniques to develop simple AI systems for public health.

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Incorporates Artificial Intelligence strategies in web applications.
Identifies philosophic questions that can emerge from the use of AI.
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
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- https://1drv.ms/p/s!Aiww0ErooSWOlkV4wO-yrdU_TMSI?e=KDS3gh]
Learning object: AI in healthcare (infographic) (ppt file) [LO2- https://1drv.ms/p/s!Aiww0ErooSWOlkfL2MGv8skIf5OB?e=fFHUN1]
Learning object: Intelligence User Interfaces concepts (infographic) [LO3- https://1drv.ms/p/s!Aiww0ErooSWOlkZw5VLP1aIl1RvI?e=rHz8Sy]
Learning object: Implementation Manual (how to build a bot integrated in a mini web site) [LO4- OA4- https://1drv.ms/w/s!Aiww0ErooSWOlkhVAitiZTNO7ZzU?e=jWPLau]
Learning object: Chatbot Ai source code [LO5]
Learning object: Mini website template - Template for building a mini web site (HTML and CSS) [LO6]

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From other sources/high-quality selected platforms:
Artificial Intelligence
What is artificial intelligence (AI)?
Introduction to AI
Turing Test – Stanford
Chinese Room
Azure Health Bot
Podcast - Building the Future - AI Portugal - Spotify
AI News

Intelligence User Interfaces
Siri
*A*lexa
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

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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
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 poses 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

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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) **[**LO1**]**

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/)
https://popcasts.pt/diagnosticos-medicos-assistidos-por-ia-convidada-joana-rocha/

Lesson 2: Intelligence Interfaces

Intelligence Interfaces concepts
The teacher starts by introduction Intelligence Interfaces as an Intelligent personal support tool that is 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, 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
*A*lexa
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

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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 of 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]**

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 incorporates 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 how to integrate the Chatbot on 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 may be used to improve the object presented.

After building and presenting the bot students are challenged to build other chatbot in groupwork. This is the **school Project** described below, in the autonomous section.

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Supplementary learning resources and educational activities

The most important supplementary educational activities are the School Research Project, which has the challenge to build a Chatbot to address the actions to be taken when symptoms appear, but, generally, during some of the sessions devoted to the development of the research project), the following activities may be organized:

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 to better public health.

c) identifying actions to fight NCDs in their community. for better expectancy and quality of life for all.

Visits to organizations interested in STEM and public health education:

FCT NOVA (visit to laboratories)
https://www.fct.unl.pt/

SILab (visit to the Social Innovation Laboratory of Instituto Superior Técnico – University of Lisbon)
http://silab.tecnico.ulisboa.pt/

ATEC – Training Center – visit to the Academy to present professional training of a technical nature
https://www.atec.pt/

Escola Nacional de Saúde Pública (https://www.ensp.unl.pt/) – activity on STEM myths and professions with challenges on SDG 3 (in relation to others) and guests from various areas and from other institutions such as Chaperone (https://chaperone.online) and ICNOVA (https://www.icnova.fcsh.unl.pt/en/homepage-2/)

(The list of partnerships will continue to be updated until the end of the project. You can consult all our partnerships here: https://pafse.eu/pt/partes-interessadas-pafse/)

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 five 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 STEM curriculums and careers
During the development of the Research Project is relevant to organize:

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:
Students will be able to propose solutions based on chatbots for healthcare contexts.
Students will be able to identify and communicate the importance of the role of AI in society and, in particular, in healthcare.
Students will be able to use technical argumentation to justify policy choices.

Teaching-learning process for school project (summary):
Development of materials (videos, tutorials, pictures).
Website and chatbot.
Presentation of the Website and chatbot in open schooling event.

Organization of the open schooling event:
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 centers, garden, museum, science fair).
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.
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

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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
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 the idea that the Turing test can show that a machine could think. D) Learning to speak Chinese.

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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.
4. Characterizes Intelligence Interfaces	**Question 4.1**: What can NOT be said about Intelligence Interfaces: A) They use applications of artificial intelligence. B) They can perform 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.

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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.
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.

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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.
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	**Question 3.1** I believe that teamwork is important to overcome obstacles and solve problems:

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critical to overcome obstacles and 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. 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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2.8. University of Minho (UMINHO)

AMENDMENTS

Since the three scenarios worked very similarly in terms of implementation and it's a matter of level of complexity, the changes made were common to the three. As mentioned on previous reports regarding the workshop and scenarios enactment, several changes were made:

1. Revised Duration of the Experience: In the initial scenarios proposal, we had outlined an extensive and resource-intensive experience. However, upon further consideration regarding teacher's comments, we have decided to revise the duration of the experience to make it shorter, more efficient and streamlined. The updated scenarios aim to be simpler for teachers since they have an incredible lack of weekly time with students, and they need guidance through all the process.

2. Reduction in Resource Usage: Our previous scenarios proposal were deemed too heavy in terms of resources. By providing too many resources, allocated in different links,etc. teachers were confused and didn't know how to use them, they don't need a lot of resources, just useful, practical ones. The updated scenarios aim to be simpler for teachers since all resources are allocated in the same digital place and were directly tested and suggested by them.

3. Streamlined Content: After careful review and consideration, we have significantly streamlined the content of the scenarios. Useless and redundant information has been identified and eliminated to ensure a clear and concise presentation of the material. This enhancement not only optimizes the participants' learning experience but also ensures that essential information is effectively communicated without unnecessary distractions.

4. Emphasis on Practicality: After receiving valuable feedback from teachers and considering the current school curriculum, we have decided to shift the theme of the experience to focus on practicality. By aligning the program with real-world challenges, opportunities and classroom daily hurdles and allowing for them to freely choose what to work on, participants will gain skills and knowledge that can be readily applied in their respective roles. This adjustment aims to ensure that the experience is more relevant, engaging, and beneficial for all involved parties.

5. Enhanced Versatility for Teachers: Recognizing the diverse needs and preferences of educators, we have introduced a higher level of versatility to the scenarios. Teachers will now have the flexibility to adjust scenarios, activities, and content to align with their specific learning objectives and the unique requirements of their audience. This customization empowers instructors to tailor the experience according to the students' backgrounds, and skill levels, resulting in a more engaging and impactful learning journey. This is extremely important to teachers because it allows them to teach something they like, as they like it, making the experience a lot more pleasant.

By implementing these changes, we are confident that the scenarios will deliver a more focused, efficient, and impactful experience for all involved.

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2.8.1. Connecting students to IT using low code development environments to promote public health and digital literacy – 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 / Health subject by teachers choice

School Subject: ICT classes/Biology/F.Q classes/Health Education classes (Interdisciplinarity[4])

Main resource: MIT App Inventor

Grade level: 7th grade (+/- 12-13 years old students)

Context and its 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
Variable, depending on ICT teachers weekly schedule (normally 40 min. per week)
Estimate (based on pilot experience): At least 4 classes of 40 min. (lesson 1- 4) and 3 sessions of 40-45 minutes for supplementary learning activities and school project (session 4 – session 7)

[4] 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.
- Students are encouraged to be creative and active “prosumers” (producers+consumers).
- Teachers are required to provide high support to students, without compromising students autonomy.

For the learning-through-teacher lessons, students will work alone/in groups (preferably) 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)

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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)

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)

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

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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;
- ⇒ 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

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- 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, responsibility.

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 *(*ex: *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.

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- 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.

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 digital format)
      https://ec.europa.eu/eusurvey/runner/STEM-Tecnologia
      https://drive.google.com/file/d/1HuvJTCmGhPlf32A8hPPWdNueDBO73261/view?usp=sharing

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- 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

STEM content

- Technical literacy.
- Basic programming expressions.
- Programming oriented math.
- Digital Literacy.
- Communicating science: Healthy lifestyles – hygiene habits.

Non-STEM content

- Teamwork
- Metacognition
- Proactivity
- Multimodality
- Autonomy

Digital Learning Objects (DLOs) and Digital Educational Resources (DERs)

New (*developed by PAFSE team*):

Given the versatile nature of MIT APP Inventor and the imperative need to let teachers choose their own way of teaching their class, suited to student's needs, the PAFSE team, after discussion with pilot schools, opted by providing general animated, intuitive, and interactive *Noocs*[5] (*Nano Open Online Courses*), used in the Pilot workshop (all available in a e-me hive: https://files.e-me4all.eu/s/GpWkoyobw2DYdAp)

1. Animated, intuitive, and interactive *Noocs*[6] (*Nano Open Online Course*) using genially[7] concerning MIT App Inventor (Basic) and concepts to communicate science through technological content.
2. Informational multimodal resources (images, videos, sound, etc.) with content, challenges and solutions regarding basic low-code programming.
3. MIT AppInventor app(s) created by the team.
4. 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); Student Interest and Choice in Technology; Informed Consent – Students; Informed Consent – Legal Representatives; Process Assessment – Observation grids, weekly meetings; Photos, Videos, Tasks; Final projects.

Available resources (link):

E-me hive with all resources: https://files.e-me4all.eu/s/GpWkoyobw2DYdAp

[5] NOOC are "nano" learning experiences that are specific, targeted to a certain skill and or competency, and can be disseminated in smaller, isolated ways.

[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.

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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
- Hygiene habits [9](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
    - 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.

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)
At least 4 classes of 40 min. (lesson 1- 4)

[8] The majority will be included in the developed DER.
[9] The topic is merely a suggestion, teachers are free to explore any health-related topic.

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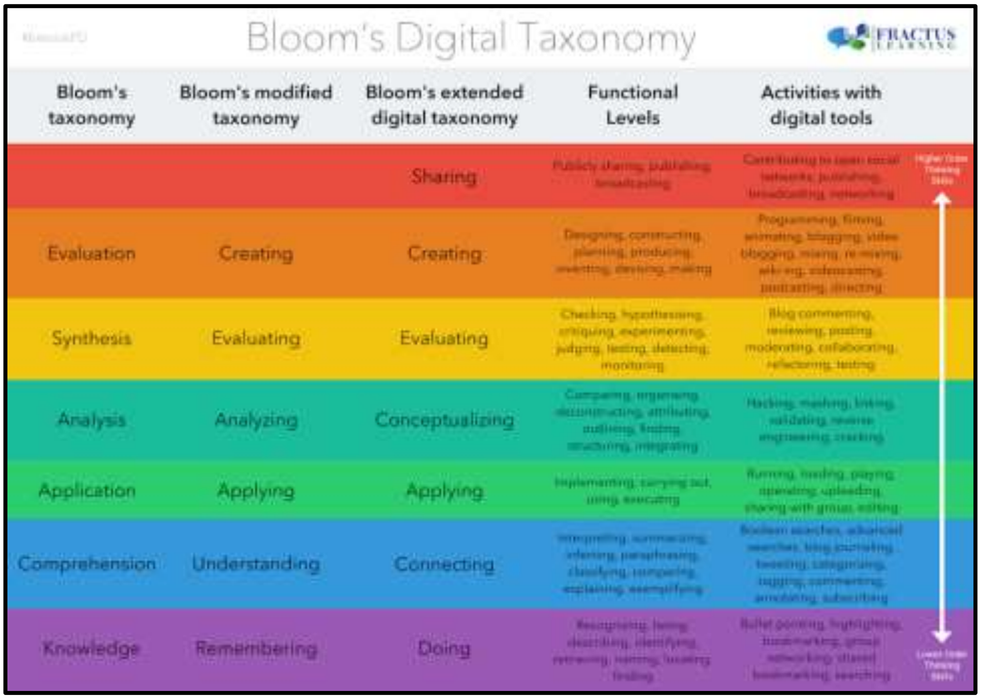
ICT teachers integrate other colleagues in the enactment of the scenario, as it aims to be interdisciplinary. The scenario provides the necessary tools for students to explore desirable behavior in an individual and public health perspective.

<u>General note:</u>

- 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 access any information there.
- The lessons will have "[Bloom's taxonomy]" as a background, which pillars are the following:



<u>Lesson 1: Introduction to key concepts</u>

<u>Learning objective</u>: 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)

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- 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.

⇒ 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".

⇒ 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); Student Interest and Choice in Technology

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

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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.

⇒ 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 worldwide 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,

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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

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.

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⇒ 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!)

⇒ **Simpler Alternative to all activities (tested in the Pilot)**: Let's keep them learning by doing – Creating the "survey" app, available in "Sessão nº 2_12dejaneiro":https://files.e-me4all.eu/s/GpWkoyobw2DYdAp

Lesson 4 and further: 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.

⇒ 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

⇒ **Alternatives:** Spaceinvaders; Presidentsquiz; Molemash

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-forward: The final countdown

This is the **School Project** described below.

Learning objective: In these final sessions, 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 student's 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.

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- 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.

These are 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

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 ideas.

School Research Project (Ciência Viva)

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 (for example) “hygiene habits”, promoting not only technology, but also public health.
Method *(summary)*: Lessons 5 to 7 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:

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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.
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):

9. Development of multimodal materials.
10. Basic Mobile Applications Sketches (or real for the most driven).
11. 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.

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Organization of the open schooling event:

6. 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).
7. 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.
8. 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".

2.8.2. Connecting students to IT using low code development environments to promote public health and digital literacy – 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 / Health subject by teachers' choice

School Subject: ICT classes/Biology/F.Q classes/Health Education classes (Interdisciplinarity[10])

Main resource: [MIT App Inventor]

10 Integrating knowledge and methods from different disciplines, using a real synthesis of approaches.

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

Context and its 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

Variable, depending on ICT teachers weekly schedule (normally 40 min. per week)
Estimate (based on pilot experience): At least 4 classes of 40 min. (lesson 1- 4) and 3 sessions of 40-45 minutes for supplementary learning activities and school project (session 4 – session 7)

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.
- Teachers are required to provide support to students, without compromising students autonomy.

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;

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    - 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)

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

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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)

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

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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)

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

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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;
- ⇒ 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

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- 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.
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:

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- 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.
4. Believes that health is the most important constituent of life.

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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.

Assessment methods

- ✓ Outcome assessment
  - Quantitative – A questionnaire (in digital format) https://ec.europa.eu/eusurvey/runner/STEM-Tecnologia https://drive.google.com/file/d/1HuvJTCmGhPlf32A8hPPWdNueDBO73261/view?usp=sharing
  - 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

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.

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Digital Learning Objects (DLOs) and Digital Educational Resources (DERs)

New (*developed by PAFSE team*):

Given the versatile nature of MIT APP Inventor and the imperative need to let teachers choose their own way of teaching their class, suited to student's needs, the PAFSE team, after discussion with pilot schools, opted by providing general animated, intuitive, and interactive *Noocs*[11] (*Nano Open Online Courses*), used in the Pilot workshop (all available in a e-me hive: https://files.e-me4all.eu/s/GpWkoyobw2DYdAp)

1. Animated, intuitive, and interactive *Noocs*[12] (*Nano Open Online Course*) using genially[13] concerning MIT App Inventor (Basic) and concepts to communicate science through technological content.
2. Informational multimodal resources (images, videos, sound, etc.) with content, challenges and solutions regarding basic low-code programming.
3. MIT AppInventor app(s) created by the team.
4. 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); Student Interest and Choice in Technology; Informed Consent – Students; Informed Consent – Legal Representatives; Process Assessment – Observation grids, weekly meetings; Photos, Videos, Tasks; Final projects.

Available resources (link):

E-me hive with all resources: https://files.e-me4all.eu/s/GpWkoyobw2DYdAp

From other sources/high-quality platforms[14]:

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[15]:
  - Referencial de educação para a saúde

[11] NOOC are "nano" learning experiences that are specific, targeted to a certain skill and or competency, and can be disseminated in smaller, isolated ways.

[12] NOOC are "nano" learning experiences that are specific, targeted to a certain skill and or competency, and can be disseminated in smaller, isolated ways.

[13] 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.

[14] The majority will be included in the developed DER.

[15] The topic is merely a suggestion, teachers are free to explore any health-related topic.

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- 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.

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)
At least 4 classes of 40 min. (lesson 1- 4)
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.

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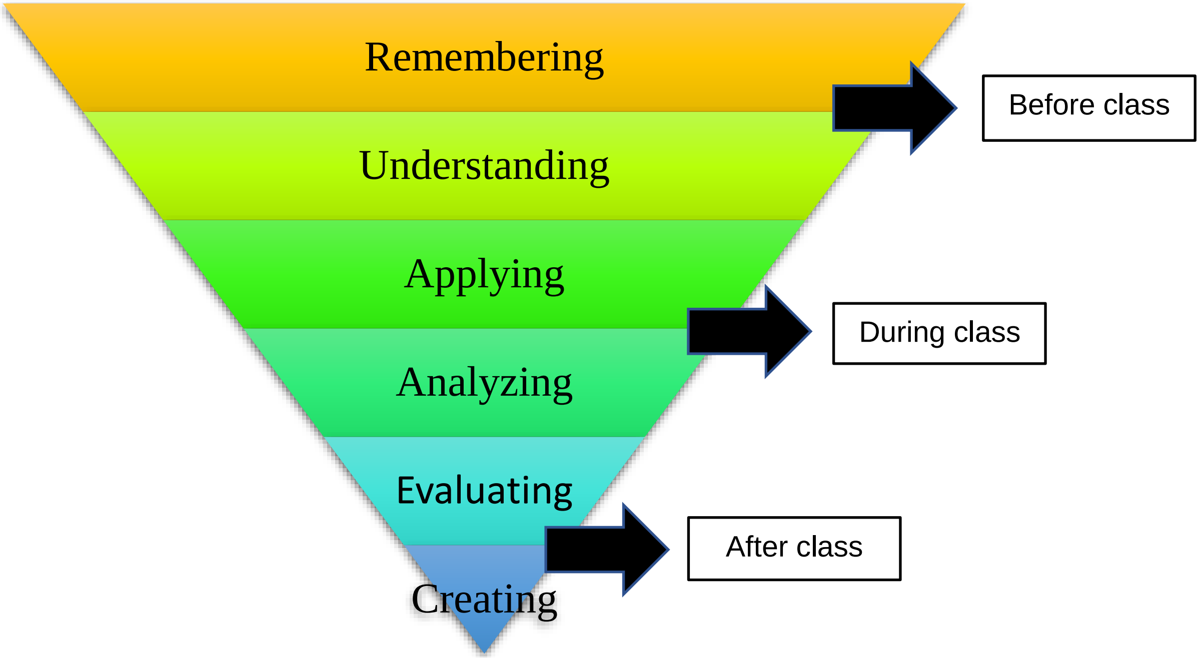

Bloom's Taxonomy for "Flipped" Classrooms; version revised by Lorin Anderson

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 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.

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⇒ 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).
- 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.

⇒ 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); Student Interest and Choice in Technology

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,*

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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
    - 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.

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- 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?
  - 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.

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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.
    - 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

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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.

⇒ **Simpler Alternative to all activities (tested in the Pilot)**: Let's keep them learning by doing – Creating the "survey" app, available in "Sessão nº 2_12dejaneiro":https://files.e-me4all.eu/s/GpWkoyobw2DYdAp

Lesson 4 and further: 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-forward: The final countdown

This is the **School Project** described below.

Learning objective: In these final sessions, 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 student's 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.

These are 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

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2. 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 5 to 7 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.

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

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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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2.8.3. Connecting students to IT using low code development environments to promote public health and digital literacy – 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 / Health subject by teachers' choice

School Subject: ICT classes/Biology/F.Q classes/Health Education classes (Interdisciplinarity[16])

Main resource: [MIT App Inventor]

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

Context and its 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.

16 Integrating knowledge and methods from different disciplines, using a real synthesis of approaches.

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Estimated Duration

Variable, depending on ICT teachers weekly schedule (normally 40 min. per week)
Estimate (based on pilot experience): At least 4 classes of 40 min. (lesson 1- 4) and 3 sessions of 40-45 minutes for supplementary learning activities and school project (session 4 – session 7)

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 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.

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

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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)

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

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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)

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:

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⇒ 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 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

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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

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.

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- 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.

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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.
- 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 digital format)
    https://ec.europa.eu/eusurvey/runner/STEM-Tecnologia
    https://drive.google.com/file/d/1HuvJTCmGhPlf32A8hPPWdNueDBO73261/view?usp=sharing

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- 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

STEM content

- Technical literacy.
- Advanced programming expressions.
- Programming oriented math.
- Digital Literacy.
- Healthy lifestyles – Physical activity.

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*):

Given the versatile nature of MIT APP Inventor and the imperative need to let teachers choose their own way of teaching their class, suited to student's needs, the PAFSE team, after discussion with pilot schools, opted by providing general animated, intuitive, and interactive *Noocs*[17] (*Nano Open Online Courses*), used in the Pilot workshop (all available in a e-me hive: https://files.e-me4all.eu/s/GpWkoyobw2DYdAp)

1. Animated, intuitive, and interactive *Noocs*[18] (*Nano Open Online Course*) using genially[19] concerning MIT App Inventor (Basic) and concepts to communicate science through technological content.
2. Informational multimodal resources (images, videos, sound, etc.) with content, challenges and solutions regarding basic low-code programming.
3. MIT AppInventor app(s) created by the team.

[17] NOOC are "nano" learning experiences that are specific, targeted to a certain skill and or competency, and can be disseminated in smaller, isolated ways.

[18] NOOC are "nano" learning experiences that are specific, targeted to a certain skill and or competency, and can be disseminated in smaller, isolated ways.

[19] 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.

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4. 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); Student Interest and Choice in Technology; Informed Consent – Students; Informed Consent – Legal Representatives; Process Assessment – Observation grids, weekly meetings; Photos, Videos, Tasks; Final projects.

Available resources (link):

E-me hive with all resources: https://files.e-me4all.eu/s/GpWkoyobw2DYdAp

From other sources/high-quality platforms[20]:

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
  - Block-based Programming in Computer Science Education
  - Block coding 101
- Physical activity[21]:
  - 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:

[20] The majority will be included in the developed DER.

[21] The topic is merely a suggestion, teachers are free to explore any health-related topic.

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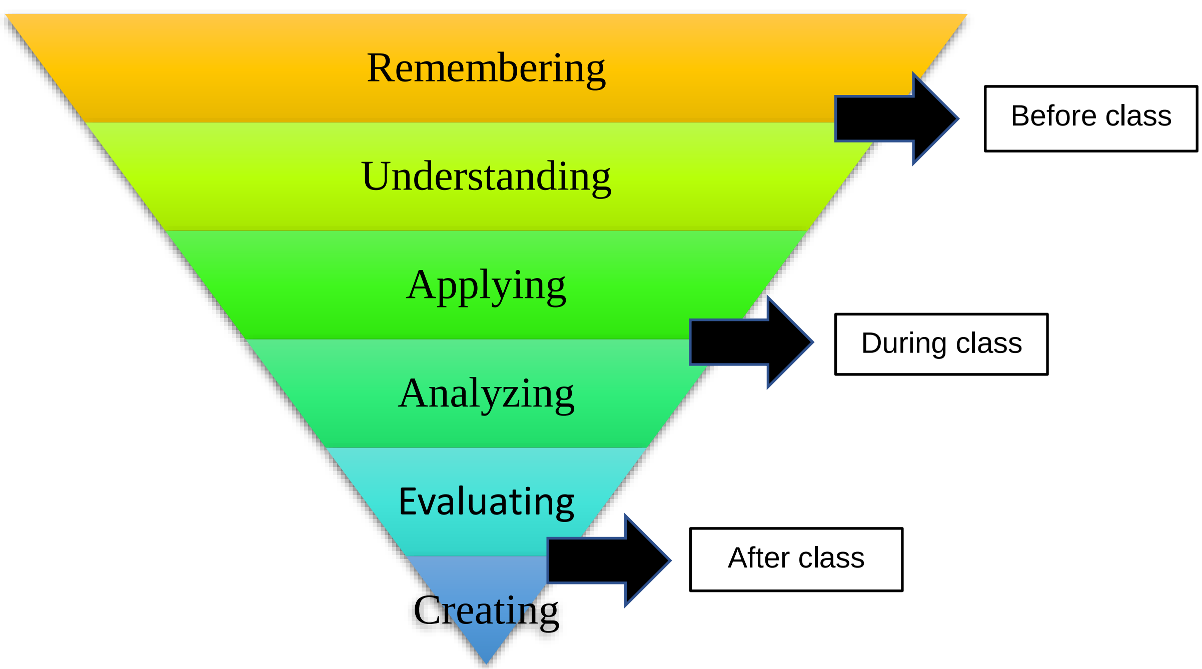
ICT classes /Biology classes /F.Q classes/Health Education classes (depending on the institution)
9h grade (+/- 14-15 years old students)
5-6 sessions/classes of 40-60 minutes
ICT teachers integrate other colleagues in the enactment of the scenario, as it aims to be interdisciplinary. The scenario provides 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.



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

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(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
    - 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,

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- 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.

⇒ 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); Student Interest and Choice in Technology.

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”

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        - 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

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.

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.

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Lesson 4: 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
Part 1: Designing Current Location Readout
Programming Part 1: The Current Location Readout
Part 2: Pinning a Location to Remember Later
Programming Part 2: Pinning a Location
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 5-forward: The final countdown

This is the **School Project** described below.

Learning objective: In these final sessions, 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 student's 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:

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    - “Priorizar” (Prioritize).
    - “Pesquisar” (Research).
    - “Planificar” (Plan)
    - Personalizar (Personalize)
    - Produzir (Produce)
  - Provision of storyboard templates to prepare the pitch.
  - Explanation of what will be evaluated.

These are 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.

School Research Project (Ciência Viva)
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 5 to 7 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:

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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.
4. 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.
    d. 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

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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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3. Annex

3.1. Amendments to UOI/CTI Educational Scenarios

Scenario Title: The mathematical representation of an epidemic: the case of SIR (Susceptible, Infectious, or Recovered) modeling – High school (Senior high school) version

Page Number	Modification
General Structure	The pilot version of the scenario ‘The mathematical representation of an epidemic: the case of SIR (Susceptible, Infectious, or Recovered) modeling’ was modified in order to make two different versions of the scenarios: one for middle/junior high school grades (K7-9), and one for high/senior high school grades (K10-12). The modifications of the high school version are shown here.
Throughout the scenario	Spelling and grammar errors were corrected. Scientific terms were replaced with more widely used terms (e.g. ‘didactic’ was replaced with ‘teaching’ in p. 4), in some cases.
Throughout the scenario	Several activities were outlined with dotted frames to show that their enactment is optional.
p.1	The clarification ‘High school (Senior high school) version’ was added in the title.
p.1	‘University of Ioannina, Ioannina, Greece’ was replaced by ‘The Educational Approaches to Virtual Reality Laboratory (EARTH Lab), Department of Primary Education, University of Ioannina, Ioannina, Greece’.
p.1	The following points were added to the ‘scientific content and its relevance to Public Health Education’ session: ‘Education on the enactment of non-pharmaceutical interventions and hygiene measures as a means of prevention of future epidemic outbreaks’. ‘Familiarization with cases of recent endemics, epidemic, and pandemics and, consequently, with the still constant problem of emerging and re-emerging infectious diseases’.
p.1	The text of the ‘Estimated duration & relevant subjects’ session was modified from ‘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.’ into ‘14 teaching hours (extended version of the scenario) organized in continuous two-hour periods if possible. 10 teaching hours (short version of the scenario). Designed for Biology, Science or Mathematics classes of high school (senior high school) grades (K10-12 grades). The scenario might also be applicable for Computer Science or Technology classes. The Biology (or Science, or Mathematics, or Computer Science) teacher could cooperate with the English language teacher in order to combine Science Learning with English Language Instruction, according to the Content and Language integrated learning (CLIL). In this way both scientific literacy and English fluency are promoted. The learning sequence is appropriate for this method since all the DLOs and SERs are available in English’.
p. 2	The following passage was added in the ‘STEM content’ session: ‘ … (natural sciences, medical sciences, mathematics, computer science) …’.

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p. 2	The passage ‘Use of mathematics in natural sciences’ was modified into ‘Use and interpretation of mathematics (numerical data, indices, variables, graphs) in natural and health sciences (scientific and health numeracy)’.
p. 2-3	The following definitions were added in the ‘Content glossary’ session, and alphabetically ordered: **‘Case fatality**: Case fatality is the probability one has to die because of a disease in a given population, given that one has been infected by the disease (conditional probability). Supposing an epidemic has infected 50 people in a population of 1000 people, and 20 of them die. The case fatality rate is 20/50 = 40%. Case fatality depends on the pathogen attributes, the disease infectivity, the underlying health condition of the citizens, vaccination, and the healthcare system’. **‘Mortality**: Mortality is the probability one has to die because of a disease in a given population. Supposing an epidemic has infected 50 people in a population of 1000 people, and 20 of them die. The mortality rate is 20/1000 = 2%. Mortality depends on the pathogen attributes, the disease infectivity, the underlying health condition of the citizens, vaccination, the healthcare system, and the frequency, or rareness, of the disease in the population’.
p. 2-3	The following passages were added in the ‘Content glossary’ session, in the definitions of ‘SIR model’, ‘infectivity’, and ‘transmissibility’: ‘…Some important conventions of the SIR model is that the population is usually considered to be stable, that all people have the same probabilities of infection and, sometimes, death, that the disease attributes (e.g. infectivity, disease duration, etc.) are considered the same for all the susceptible people of the population, and that recovered people cannot catch the disease again…’. ‘…vaccination and external conditions (e.g. non pharmaceutical interventions such as medical masks and social distance)…’. ‘…health condition of the susceptible person and vaccination…’.
p. 4	The following passage was added in the definition of ‘inquiry based learning’: ‘…In structured inquiry students are given the research question to-be-answered, as well as detailed step-by-step guidance of the entire process of inquiry. In guided inquiry student are only given the research question to-be-answered and the decision-making processes about the research procedure are set up to them’.
p. 4	The following definition was added in the ‘Pedagogical glossary’ session, and alphabetically ordered: **‘Problem solving**: The problem solving approach includes students groups practicing higher thinking skills and making decisions in to analyze a given problem and propose solutions to it. At first, the problem settings are described to students along with the desirable aim, and some basic limitations. Each groups analyzes the problem and comes up with as more and as diverse solutions possible (creative thinking), and then evaluates these ideas (critical thinking) through group discussions, pros and cons comparisons, assessment according to criteria, pilot tests, tests, or other ways, and come down to a final proposed solution, as detailed as possible. After testing the proposed solution, or getting feedback on it, the group might have to repeat the steps of improve the solution’.
p. 5	The following learning goal was added: ‘Public health literacy’.
p. 5	The words ‘desirable’ were removed from the ‘Prerequisite knowledge and skills’ session.
p. 5	The following points was added in the ‘Prerequisite knowledge and skills’: Intermediate, or at least limited, fluency in English in case that DLOs and SERs

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	other than the ones of the PAFSE repository are used.
p. 7	The last point of the 'Teacher professional development actions' session was modified from 'The utilization of the scenario's digital learning objects in the inquiry-based learning process' into 'Inquiry-based-learning contextualization of the scenario's digital learning objects (structured inquiry, guided inquiry, case study, argumentation, problem solving)'.
p. 7	The following point was added in the 'Teacher professional development workshop' session: 'Handling of the digital learning objects of the scenario'.
p. 7-8	DLOs II and IV were renamed: 'Map and timeline of communicable diseases' 'SIR model of an epidemic and non-pharmaceutical interventions'
p. 8	Addition of the following link of the DLO III: 'http://photodentro.pafse.eu/handle/8586/49'.
p. 9	Addition of SER IX, as well as its link and description: 'E-me platform H5P tools for the school project H5P tools of the e-me platform (https://e-me4all.eu/). By choosing 'e-me content' students can use the 'Course Presentation' tool to create an interactive and multimodal presentation, with texts, images, videos, short questions, etc, for the health promotion campaign'.
p. 9	Addition of the note: 'Some educational activities have been framed … optional homework for students interested'
p. 9	Addition of the learning objectives table under the '1st teaching hour'.
p. 10	Addition of the following texts and phrases under the '1st teaching hour': '…For example, 2-3 non-pharmaceutical interventions could be provided per student, maybe different for each student. There could be a numbered list with non-pharmaceutical interventions and each student could randomly be given 3 numbers.…'. 'The activity aims to the externalization … should sincerely express themselves'. 'The teacher must make a free subscription to the Gizmos platform and issue class passwords for students in order to use the simulation'. ' … feces, insects, …' 'During the group brainstorming, students are urged to find as many non pharmaceutical interventions they can'.
p. 10	The following passage was set into a frame indicating being optional: 'Next, the phase of inquiry begins … independent and dependent variables'.
p. 10-11	Addition of the learning objectives table under the '2nd teaching hour'.
p. 11	The following passage was set into a frame indicating being optional: 'During this hour students try to answer … possible causes of this situation'.
p. 11	The word 'biomedical' was changed with the word 'medical'.
p. 11-12	Addition of the following texts under the '2nd teaching hour': 'The use of DLO I could be omitted in favor of time economy or simplicity, and the relevant tasks (e.g. finding diseases that affected students' country, distinction of endemics, epidemics, and pandemics) could be answered with DLO II'. 'Measles, MERS, Zika disease and Avian Influenza might offer appropriate examples for this activity, without excluding other diseases, as well'. 'COVID-19, and Swine Influenza might offer appropriate examples for this activity, without excluding other diseases, as well'. 'Measles, Rubella, HIV infections, and COVID-19 might offer appropriate

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	examples for this activity, without excluding other diseases, as well'. 'The teacher could suggest student elaborate … other diseases of the DLO'.
p. 12	Addition of the learning objectives table under the '3rd teaching hour'.
p. 12-13	Addition of the following texts under the '3rd teaching hour': 'It is suggested to emphasize the differences between independent and dependant, and between qualitative and quantitative variables during all the inquiry activities (3rd to 8th hours), so that students are practiced in these distinctions'. 'Some SIR graphs for students' practice can be taken from the DLO III environment'. 'The inquiry process with the DLO III … during the following hours'.
p. 13	Addition of the learning objectives table under the '4th teaching hour'.
p. 13	Addition of the following texts under the '4th teaching hour': 'Which consequence of an epidemic is the most important … to be developed against the disease'. 'The activity above concerning a hypothetical … with the aid of the next digital learning objects'.
p.13	The following passage was set into a frame indicating being optional: 'Finally, students form … A discussion on the proposed plans follows'.
p. 14	Addition of the learning objectives table under the '5th teaching hour'.
p. 14-15	Addition of the following texts and passages under the '5th teaching hour': 'A short guide with the initial values for the simulation parameters to-be-used should be given to students for the initiation of the inquiry activity, since some parameters values differ from the default ones (e.g. asymptomatic rate)'. '…What is considered as tolerable is defined by the given upper limit of the Healthcare System capacity'. 'The rule of triple repetition … by each student group'.
p. 15	Addition of the learning objectives table under the '6th teaching hour'.
p. 16	Addition of the following text under the '6th teaching hour': 'During this hour students have to work much more independently … or guidance questions by the teacher'.
p. 16	The following passage was set into a frame indicating being optional: 'Finally, students opt for the simulation mode … is discussed in class'.
p. 16	Addition of the learning objectives table under the '7th teaching hour'.
p. 16-17	Addition of the following texts and passages under the '7th teaching hour': 'The exploration of the virtual environment of the simulation could be done through direct instruction with the aid of a projector machine'. ' …SERs IV and V could be projected with a projector machine and the reason of the high effectiveness of the use of medical masks could be explained in the grounds of these SERs. Students are expected reach themselves to this conclusion'. 'The comparisons do not have to be as detailed as the previous ones'. 'The activity, which is a series of numerous alternative options for activities, is might be optional and aiming only to 'advanced' groups, that have completed the previously assigned tasks earlier than the other student groups'.
p. 17	The following passage was set into a frame indicating being optional: 'Students are assigned to study … for some student groups'.
p. 17	Addition of the learning objectives table under the '8th teaching hour'.
p. 18	Addition of the following texts and passages under the '8th teaching hour': 'The activity, which comprises of a series … at least two'.

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	'The discussion might focus on 2-4 indicative questions on which most student group answered'. 'The activity is optional and it is an introduction … methodologies and approaches'. 'The comparison of the three SIR models with one another, and with the real world are quite important for the distinction between the concepts of models and the real natural phenomena in the students' conceptualizations.
p. 18	The following passage was set into a frame indicating being optional: 'Next, each group is assigned with a problem … with comments for further improvement'.
p. 18-19	Addition of the learning objectives table under the '9th teaching hour'.
p. 19	Addition of the following passage under the '9th teaching hour': ' …Hints, feedback, or guiding questions should be provided to students when they feel blocked or run out of ideas, specifically adapted to each student group'.
p. 19	Addition of the learning objectives table under the '10th teaching hour'.
p. 20	Addition of the following text under the '10th teaching hour': 'The second part of the research project … time management'.
p. 20	Addition of the learning objectives table under the '11th teaching hour'.
p. 20	The following passage was set into a frame indicating being optional: 'During the eleventh teaching hour … groups are formed again'
p. 21	Addition of the following passage under the '11h teaching hour': 'The activity is suggested providing that the school class climate among student is suitable for the proper cooperation and mutual help among students about the lesson'.
p. 21	Addition of the learning objectives table under the '12th teaching hour'.
p. 21	Addition of the learning objectives table under the '13th – 14th teaching hour'.
p. 22	The entire session 'Short version of the scenario' was added. The passage 'The initial (extended version) … are the following ones:' was added The table was added.
p. 24-26	The following references were added and alphabetically ordered: Amidon, T. R., Nielsen, A. C., Pflugfelder, E. H., Richards, D. P., & Stephens, S. H. (2021). Visual risk literacy in "flatten the curve" COVID-19 visualizations. *Journal of Business and Technical Communication*, 35(1), 101-109. Ancker, J. S., & Kaufman, D. (2007). Rethinking health numeracy: a multidisciplinary literature review. *Journal of the American Medical Informatics Association*, 14(6), 713-721. Bechraki, E., Mavrikaki, E., Gialamas, V., & Galanaki, E. (2022). Development and validation of an instrument for the health literacy assessment of secondary school students (HeLiASeSS). HealthEducation, 122(6), 678-699. Bybee, R. W. (2014). The BSCS 5E instructional model: Personal reflections and contemporary implications. *Science and Children*, 51(8), 10-13. Chalkidis, D., Santos, C., & Mikropoulos T. A. (2022). Partnerships for Science Education: Public health education and awareness with digital technologies. *13th Conference of European Researchers in Didactics of Biology (ERIDOB)*, 29th August -2nd September 2022, Nicosia, Cyprus. Constantinou, C. P., Tsivitanidou, O. E., & Rybska, E. (2018). What is inquiry-based science teaching and learning?. In *Professional development for inquiry-based science teaching and learning* (pp. 1-23). Springer, Cham. Gaintatzis, P., Chalkidis, D., Iatraki, G., Mikropoulos, T. A., Megalou, E., Santos, C. (2023). Designing Digital Learning Objects for Public Health. *4th Panhellenic*

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	Conference in e-learning and Open Educational Resources. 18-19 March 2023, Athens, Greece. Gillies, R. M. (2020). *Inquiry-based science education*. CRC Press. Gordis, L. (2016). *Epidemiology* (Fifth Edition). Elsevier. Jimoyiannis, A., Christopoulou, E., Paliouras, A., Petsos, A., Saridaki, A., Toukiloglou, P., & Tsakonas, P. (2013). Design and development of learning objects for lower secondary education in Greece: The case of computer science e-books. *Proc. of EDULEARN13 Conference*, 41-49. Johnson, T., & McQuarrie, B. (2009). *Mathematical modeling of diseases: Susceptible-infected-recovered (SIR) model*. University of Minnesota, Morris, Math, 4901. Jonassen, D. H., Carr, C., & Yueh, H. P. (1998). Computers as mindtools for engaging learners in critical thinking. *TechTrends,* 43(2), 24-32. Joyce, B., Weil, M., & Calhoun, E. (2017). *Models of Teaching* (Ninth Edition). Pearson. Kagan, S., & Kagan, M. (2009). *Kagan Cooperative Learning*. Kagan Publishing. Kilstadius, M., & Gericke, N. (2017). Defining contagion literacy: A Delphi study. *International Journal of Science Education*, 39(16), 2261-2282. Kollosche, D., & Meyerhöfer, W. (2021). COVID-19, mathematics education, and the evaluation of expert knowledge. *Educational Studies in Mathematics*, 108(1), 401-417. Mavrikaki, E., Kyridis, A., & Antonatou, C. (2012). Greek senior high school students' attitudes about science and the scientific community after the H1N1 pandemic and the conflicts within the scientific community as it appeared in the Mass Media. *Journal of Studies in Education*, 2(IKEEART-2014-1839), 32-46. McGreal, R. (2004). Learning objects: A practical definition. *International Journal of Instructional Technology and Distance Learning (IJITDL)*, 9(1). Megalou, E., & Kaklamanis, C. (2014). Photodentro LOR, the Greek national learning object repository. *INTED2014 proceedings*, 309-319. Minner, D. D., Levy, A. J., & Century, J. (2010). Inquiry-based science instruction—what is it and does it matter? Results from a research synthesis years 1984 to 2002. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, 47(4), 474-496. Morens, D. M., & Fauci, A. S. (2020). Emerging pandemic diseases: how we got to COVID-19. *Cell*, 182(5), 1077-1092. Paakkari, L., & Okan, O. (2020). COVID-19: health literacy is an underestimated problem. *The Lancet Public Health,* 5(5), e249-e250. Pedaste, M., Mäeots, M., Siiman, L. A., De Jong, T., Van Riesen, S. A., Kamp, E. T., Manoli, C. C., Zacharia, Z., & Tsourlidaki, E. (2015). Phases of inquiry-based learning: Definitions and the inquiry cycle. *Educational research review*, 14, 47-61. Rönner, A. C., Jakobsson, A., & Gericke, N. (2023). Cough, sneeze, pass it on–pupils' understanding of infectious diseases in the aftermath of COVID-19. *Journal of Biological Education*, 1-13. Salama, A. M. (2020). Coronavirus questions that will not go away: interrogating urban and socio-spatial implications of COVID-19 measures. *Emerald Open Research*, 2. Taber, K. S. (2017). Models and modelling in science and science education. In *Science education* (pp. 263-278). Brill. Wiley, D., Bliss, T. J., & McEwen, M. (2014). Open educational resources: A review of the literature. In *Handbook of research on educational communications*

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	and technology (pp. 781-789).
p. 25	The following reference was removed: Muellner, U., Fournié, G., Muellner, P., Ahlstrom, C., & Pfeiffer, D. U. (2018). Epidemix - An interactive multi-model application for teaching and visualizing infectious disease transmission. *Epidemics*, 23, 49-54.

Scenario Title: The mathematical representation of an epidemic: the case of SIR (Susceptible, Infectious, or Recovered) modeling – Middle school (Junior high school) version

Page Number	**Modification**
General Structure	The pilot version of the scenario 'The mathematical representation of an epidemic: the case of SIR (Susceptible, Infectious, or Recovered) modeling' was modified in order to make two different versions of the scenarios: one for middle/junior high school grades (K7-9), and one for high/senior high school grades (K10-12). The modifications of the middle school version are shown here.
Throughout the scenario	Spelling and grammar errors were corrected. Scientific terms were replaced with more widely used terms (e.g. 'didactic' was replaced with 'teaching' in p. 4), in some cases.
Throughout the scenario	Several activities were outlined with dotted frames to show that their enactment is optional.
Throughout the scenario	The activities were re-organized in order to decrease the duration of the scenario.
p.1	The clarification 'High school (Senior high school) version' was added in the title.
p.1	'University of Ioannina, Ioannina, Greece' was replaced by 'The Educational Approaches to Virtual Reality Laboratory (EARTH Lab), Department of Primary Education, University of Ioannina, Ioannina, Greece'.
p. 1	The following changes were made in the 'Overview' session: The phrase '…three-part school project…' has been changed to '…school project with three options …'. The word 'part' has been changed with the word 'option'.
p.1	The following points were added to the 'scientific content and its relevance to Public Health Education' session: 'Education on the enactment of non-pharmaceutical interventions and hygiene measures as a means of prevention of future epidemic outbreaks'. 'Familiarization with cases of recent endemics, epidemic, and pandemics and, consequently, with the still constant problem of emerging and re-emerging infectious diseases'.
p.1	The text of the 'Estimated duration & relevant subjects' session was modified from '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.' into '12 teaching hours (extended version of the scenario) organized in continuous two-hour periods if possible. 6 teaching hours (short version of the scenario). Designed for Biology, Science or Mathematics classes of middle school (junior high school) grades (K7-9 grades). The scenario might also be applicable for Computer Science or Technology classes. The Biology (or Science, or Mathematics, or Computer Science) teacher could cooperate with the English language teacher in order to combine Science Learning with English Language Instruction, according to the Content and Language integrated learning (CLIL). In

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	this way both scientific literacy and English fluency are promoted. The learning sequence is appropriate for this method since all the DLOs and SERs are available in English'.
p. 2	The following passage was added in the 'STEM content' session: ' … (natural sciences, medical sciences, mathematics, computer science) …'.
p. 2	The passage 'Use of mathematics in natural sciences' was modified into 'Use and interpretation of mathematics (numerical data, indices, variables, graphs) in natural and health sciences (scientific and health numeracy)'.
p. 2-3	The following definitions were added in the 'Content glossary' session, and alphabetically ordered: **'Case fatality**: Case fatality is the probability one has to die because of a disease in a given population, given that one has been infected by the disease (conditional probability). Supposing an epidemic has infected 50 people in a population of 1000 people, and 20 of them die. The case fatality rate is 20/50 = 40%. Case fatality depends on the pathogen attributes, the disease infectivity, the underlying health condition of the citizens, vaccination, and the healthcare system'. **'Mortality**: Mortality is the probability one has to die because of a disease in a given population. Supposing an epidemic has infected 50 people in a population of 1000 people, and 20 of them die. The mortality rate is 20/1000 = 2%. Mortality depends on the pathogen attributes, the disease infectivity, the underlying health condition of the citizens, vaccination, the healthcare system, and the frequency, or rareness, of the disease in the population'.
p. 2-3	The following passages were added in the 'Content glossary' session, in the definitions of 'SIR model', 'infectivity', and 'transmissibility': '…Some important conventions of the SIR model is that the population is usually considered to be stable, that all people have the same probabilities of infection and, sometimes, death, that the disease attributes (e.g. infectivity, disease duration, etc.) are considered the same for all the susceptible people of the population, and that recovered people cannot catch the disease again…'. '…vaccination and external conditions (e.g. non pharmaceutical interventions such as medical masks and social distance)…'. '…health condition of the susceptible person and vaccination…'.
p. 4	The following passage was added in the definition of 'inquiry based learning': '…In structured inquiry students are given the research question to-be-answered, as well as detailed step-by-step guidance of the entire process of inquiry. In guided inquiry student are only given the research question to-be-answered and the decision-making processes about the research procedure are set up to them'.
p. 4	The following definition was added in the 'Pedagogical glossary' session, and alphabetically ordered: **'Problem solving**: The problem solving approach includes students groups practicing higher thinking skills and making decisions in to analyze a given problem and propose solutions to it. At first, the problem settings are described to students along with the desirable aim, and some basic limitations. Each groups analyzes the problem and comes up with as more and as diverse solutions possible (creative thinking), and then evaluates these ideas (critical thinking) through group discussions, pros and cons comparisons, assessment according to criteria, pilot tests, tests, or other ways, and come down to a final proposed solution, as detailed as possible. After testing the proposed solution, or getting feedback on it, the group might have to repeat the steps of improve the solution'.
p. 5	The following learning goal was added:

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	‘Public health literacy’.
p. 5	The following changes were made in the ‘Classroom organization requirements’. The phrase ‘8th teaching hour’ has been changed to ‘7th teaching hour’. The phrase ‘9th until the 14th’ has been changed to ‘8th until the 12th’
p. 5	The words ‘desirable’ were removed from the ‘Prerequisite knowledge and skills’ session.
p. 5	The following points was added in the ‘Prerequisite knowledge and skills’: Intermediate, or at least limited, fluency in English in case that DLOs and SERs other than the ones of the PAFSE repository are used.
p. 7	The last point of the ‘Teacher professional development actions’ session was modified from ‘The utilization of the scenario’s digital learning objects in the inquiry-based learning process’ into ‘Inquiry-based-learning contextualization of the scenario’s digital learning objects (structured inquiry, guided inquiry, case study, argumentation, problem solving)’.
p. 7	The following point was added in the ‘Teacher professional development workshop’ session: ‘Handling of the digital learning objects of the scenario’.
p. 7-8	DLOs II and IV were renamed: ‘Map and timeline of communicable diseases’ ‘SIR model of an epidemic and non-pharmaceutical interventions’
p. 8	Addition of the following link of the DLO III: ‘http://photodentro.pafse.eu/handle/8586/49’.
p. 8	The DLO V was removed, along with its link, and the explanatory text below: ‘Transmission routes of diseases … made by Gizmos’.
p. 8	The DLO VI was renamed to DLO V
p. 8	The SERs II, VI, and VII were removed, along with their links, and the explanatory texts below: ‘The SIR graph … visualization of an SIR graph’. ‘Scientific modeling … through examples’ Global COVID-19 database I … of their choice’
p. 8	The following SERs were renumbered as following: SER II → removed SER III → SER II SER IV →SER III SER V → SER IV SER VI → removed SER VII → removed SER X →SER V
p. 8	Addition of SER VI, as well as its link and description: ‘E-me platform H5P tools for the school project H5P tools of the e-me platform (https://e-me4all.eu/). By choosing ‘e-me content’ students can use the ‘Course Presentation’ tool to create an interactive and multimodal presentation, with texts, images, videos, short questions, etc, for the health promotion campaign’.
p. 9	Addition of the note: ‘Some educational activities have been framed … optional homework for students interested’
p. 9	Addition of the learning objectives table under the ‘1st teaching hour’.
p. 9-10	The following texts and passages were removed under the ‘1st teaching hour’: ‘Next, the phase of inquiry begins … independent and dependent variables’.

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	'…other than the ones covered by DLO V…'
p. 9-10	Addition of the following texts and phrases under the '1st teaching hour': '…For example, 2-3 non-pharmaceutical interventions could be provided per student, maybe different for each student. There could be a numbered list with non-pharmaceutical interventions and each student could randomly be given 3 numbers.…'. 'The activity aims to the externalization … should sincerely express themselves'. ' … feces, insects, …' 'During the group brainstorming, students are urged to find as many non pharmaceutical interventions they can'.
p. 10	Addition of the learning objectives table under the '2nd teaching hour'.
p. 10	The following passage was set into a frame indicating being optional: 'During this hour students try to answer … possible causes of this situation'.
p. 10	The word 'biomedical' was changed with the word 'medical'.
p. 10-11	Addition of the following texts under the '2nd teaching hour': 'The use of DLO I could be omitted in favor of time economy or simplicity, and the relevant tasks (e.g. finding diseases that affected students' country, distinction of endemics, epidemics, and pandemics) could be answered with DLO II'. 'Measles, MERS, Zika disease and Avian Influenza might offer appropriate examples for this activity, without excluding other diseases, as well'. 'COVID-19, and Swine Influenza might offer appropriate examples for this activity, without excluding other diseases, as well'. 'Measles, Rubella, HIV infections, and COVID-19 might offer appropriate examples for this activity, without excluding other diseases, as well'. 'The teacher could suggest student elaborate … other diseases of the DLO'.
p. 11	Addition of the learning objectives table under the '3rd teaching hour'.
p. 11-12	The phrase '3rd to 8th' was replaced by '3rd to 6th'. The phrase '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 DLOs III, VI and IV' was replaced by 'After the first two teaching hours they change the SIR simulation they work on, moving from a simpler to the more complex and realistic ones. The SIR models they use are DLOs III, V and IV'.
p. 11	The following passage was removed: '…SER II…'
p. 11-12	Addition of the following texts under the '3rd teaching hour': 'It is suggested to emphasize the differences between independent and dependant, and between qualitative and quantitative variables during all the inquiry activities (3rd to 8th hours), so that students are practiced in these distinctions'. ' … The shape and the meaning of the SIR graphs should be taught explicitly with numerous examples and case studies. Different SIR graphs and epidemic curves and be compared and contrasted to one another. The video SER II could be shown in order to match the real progress of an epidemic outbreak to the shape of the SIR graph in real time'. 'Some SIR graphs for students' practice can be taken from the DLO III environment'. 'The inquiry process with the DLO III … during the following hours'.
p. 12	The passage 'Students go on examining … on the transmission route' is transferred from the 3rd to the 4th teaching hour.

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p. 12	Addition of the learning objectives table under the ‘4th teaching hour’.
p. 12-13	Addition of the following texts under the ‘4th teaching hour’: ‘Which consequence of an epidemic is the most important … to be developed against the disease’. ‘The activity above concerning a hypothetical … with the aid of the next digital learning objects’.
p.13	The following passage was set into a frame indicating being optional: ‘Finally, students form … A discussion on the proposed plans follows’.
p. 13-14	The activities of the 5th and 6th teaching hours (pilot version of the scenario) are rearranged so as to be fused into a single 5th teaching hour (final version of the scenario).
p. 13	The phrase ‘social distancing is’ is
p. 13	Addition of the learning objectives table under the ‘5th teaching hour’.
p. 13-14	The phrase ‘the following two teaching hours’ was replaced by ‘this teaching hour’. The phrase ‘DLO VI’ was replaced by the phrase ‘DLO V’.
p. 13-14	Addition of the following texts and passages under the ‘5th teaching hour’: ‘A short guide with the initial values … in English’. ‘…What is considered as tolerable is defined by the given upper limit of the Healthcare System capacity’. ‘… Half of the groups are assigned to study a disease of low infectivity (low infectious radius) and the other half of the groups study a disease of high infectious disease (high infectious radius)…’. ‘…Afterwards, the teacher organizes the indicative results of the four cases (low infectivity/no measures, low infectivity/social distancing, high infectivity/no measures, high infectivity/social distancing). The cases are compares in pairs, and…’. ‘…and students discuss what ‘social distancing’ means in real life conditions…’. ‘The teacher shows what happens … in authentic life settings’. ‘A short, yet more extensive study … travelling be restricted’.
p. 13-14	The following passages and texts were removed: ‘…They also try to discover correlations between the studied variables’. ‘…three times for each case and extract the means’. ‘…Low infectious radius is chosen to represent a disease of low infectivity…’. ‘Afterwards, students select a high infection … a low infectious disease’. ‘…A short discussion follows on the inquiry conclusions and relevant students’ experience from the COVID-19 pandemic with the participation of the entire class’.
p. 14	The following passage was set into a frame indicating being optional: ‘As a last phase of inquiry … all the necessary tests’.
p. 14	The 6th teaching hour session ‘After having studied the effect…an epidemic is discussed in class’ is completely removed.
p. 14	The ‘7th teaching hour’ is renamed to ‘6th teaching hour’.
p. 14-15	Addition of the learning objectives table under the ‘6th teaching hour’.
p. 15	Addition of the following texts and passages under the ‘6th teaching hour’: ‘The exploration of the virtual environment of the simulation could be done through direct instruction with the aid of a projector machine’. ‘ …SERs III and IV could be projected with a projector machine and the reason of the high effectiveness of the use of medical masks could be explained in the grounds of these SERs. Students are expected reach themselves to this conclusion’. ‘The comparisons do not have to be as detailed as the previous ones’.

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	'The activity, which is a series of numerous alternative options for activities, is might be optional and aiming only to 'advanced' groups, that have completed the previously assigned tasks earlier than the other student groups'.
p. 15	The following passage was set into a frame indicating being optional: 'Students are assigned to study … for some student groups'.
p. 15	The phrase 'SER IV' was replaced by 'SER III'. The phrase 'SER V' was replaced by 'SER IV'.
p. 16	The '8th teaching hour' was replaced by '7th teaching hour'.
p. 16	Addition of the learning objectives table under the '7th teaching hour'.
p. 16	Addition of the following texts and passages under the '7th teaching hour': 'The teacher chooses certain research questions, namely two or three'. 'Moreover, they are urged to come up with different alternative research designs than the ones been done'. 'The activity is optional and it is an introduction … methodologies and approaches'. 'The comparison of the three SIR models with one another, and with the real world are quite important for the distinction between the concepts of models and the real natural phenomena in the students' conceptualizations'.
p. 16	The following passages were removed: 'After each group has finished …earlier than the others'. 'The video SER VI is presented and commented in a final conceptualization of the nature, the function and the usefulness of a scientific model'.
p. 16-18	The structure of the scenario was rearranged. The activities from the 9th to 12th teaching hours (pilot version of the scenario) were rearranged so as to fit the 8th to 9th teaching hours (final version of the scenario).
p. 16	The title of the session '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)' was changed to '8th – 9th teaching hours - Using SIR models for policy making, model precision checking and informing the public (School project)'.
p. 16-18	The texts of the 9th to 12th teaching hours of the pilot version of the scenario are rearranged to a great extent.
p. 16-17	Addition of the learning objectives table under the '8th - 10th teaching hours'.
p. 18	The following passage was set into a frame indicating being optional: 'In order to make links to … have already learnt'.
p. 17-18	Addition of the following passages and texts under the '8th – 10th teaching hours': 'Students form four- or five-member groups … demand different skills'. ' …Hints, feedback, or guiding questions should be provided to students when they feel blocked or run out of ideas, specifically adapted to each student group…'. 'Students can, also, navigate … each measure was'. 'The second project option … tendencies in Mathematics and Science…'. 'A detailed worksheet … write a final report'. 'The second part of the research project … in English and Greek'. 'During the 9th teaching hour … difficulties they found'. 'The activity is suggested providing that the school class climate among students is suitable for the proper cooperation and mutual aid among students about the lesson'. 'A detailed worksheet in order to scaffold students that choose this project is necessary, in order to write a final report'. 'The third project option … communication skills, instead'.

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	'…They must use resources …they can be used…'. '…Students can, also, include information about recent epidemics, endemics, and pandemics, as well as information and resources found on the Internet …'. 'The final project outcome …had not thought of'.
p. 17-18	The following texts and passages were removed: 'The 9th teaching hour aims at the initiation of the school project…' 'The main activity of the 9th hour follows, which the first part of the three-part school research project…' 'At the beginning of the 10th hour …some groups might face'. 'Then, the first part of the project …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, which …'. 'During the eleventh teaching hour …groups are formed again'. 'The students responsible for designing the administration plan of an epidemic complete their experimentation with models and the selection of precautionary measures'. '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 as the study'. '…to one another, as well as …' 'During the twelfth teaching hour students are assigned to carry out the third part of the school project …'.
p. 17-18	The phrase '…Four- or five-member groups are formed and each one …' was replaced by '…Each group…'. The phrase '… the three SIR …' was replaced by the '…one or more of the three SIR …'. The phrase '…DLOs III, IV, VI…' was replaced by '…DLOs III, IV, V…'. The phrase '…be functional and viable …' was replaced by '…be as functional and as viable…'. The phrase '…of a real society…' was replaced by '…of a real society if possible…'. The phrase 'SERs VII and VIII' was replaced by 'SER V'. The phrase '…the compatibility of the three SIR…' was replaced by '…the compatibility of one of the three SIR …'. The phrase '…four slides (SER IX)…' was replaced by '…ten slides, (SER VI)…'.
p. 17-18	The titles of the 10th, 11th and 12th teaching hours were removed.
p. 18	The 13th-14th teaching hours are renamed to 11th-12th teaching hours.
p. 18-19	Addition of the learning objectives table under the '13th – 12th teaching hour'.
p. 19	The phrase '… has completed the three project outcomes …' has been changed to '…has completed one of the three project outcomes…'. The phrase '… part of the project …' has been changed to '…project options…'.
p. 19-20	The entire session 'Short version of the scenario' was added. The passage 'The initial (extended version) … are the following ones:' was added The table was added.
p. 21-23	The following references were added and alphabetically ordered: Amidon, T. R., Nielsen, A. C., Pflugfelder, E. H., Richards, D. P., & Stephens, S. H. (2021). Visual risk literacy in "flatten the curve" COVID-19 visualizations. *Journal of Business and Technical Communication*, 35(1), 101-109. Ancker, J. S., & Kaufman, D. (2007). Rethinking health numeracy: a multidisciplinary literature review. *Journal of the American Medical Informatics*

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p. 22	The following reference was removed: Muellner, U., Fournié, G., Muellner, P., Ahlstrom, C., & Pfeiffer, D. U. (2018). Epidemix - An interactive multi-model application for teaching and visualizing infectious disease transmission. *Epidemics*, 23, 49-54.

Scenario Title: Social determinants of health during an epidemic/pandemic outbreak – High school (Senior high school) version

Page Number	**Modification**
General Structure	The pilot version of the scenario '' was modified in order to make two different versions of the scenarios: one for middle/junior high school grades (K7-9), and one for high/senior high school grades (K10-12). The modification of the high school version is shown here.
Throughout the scenario	Spelling and grammar errors were corrected. Scientific terms where replaced in some cases with more widely used terms (e.g. 'didactic' was replaced with 'teaching' in p. 3).
Throughout the scenario	Several activities were characterized as 'optional'.
Throughout the scenario	Several activities were outlined with dotted frames to show that their enactment is optional.
p.1	The clarification 'High school (Senior high school) version' was added in the title.
p.1	'University of Ioannina, Ioannina, Greece' was replaced by 'The Educational Approaches to Virtual Reality Laboratory (EARTH Lab), Department of Primary Education, University of Ioannina, Ioannina, Greece'.
p.1	The following points were added to the 'scientific content and its relevance to Public Health Education' session: 'Social and health disparities pose a serious issue in public health promotion. Students have to be aware of this problem in order to evolve to active citizens'. 'The notion of health is contextualized in authentic societal settings (health policies), and an authentic way of health-related decision-making, including emotional, social, economic, and ethical factors'. 'Some environmental determinant of health are approached, and more particularly, the major problem of the origin of Emerging Infectious Diseases, in the context of the One Health Approach'.

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p.1	The text of the 'Estimated duration & relevant subject' session was modified from '12 teaching hours, organized in continuous two-hour periods if possible. Designed for Biology, Science or Social Science classes of K7-9 grades' into '12 teaching hours (extended version of the scenario), organized in continuous two-hour periods if possible. 10 teaching hours (short version of the scenario). Designed for Biology, Science, Health Science, or Social Science classes of high school (senior high school) grades (K10-12 grades). The Biology (or Science, or Health Science, or Social Science) teacher could cooperate with the English language teacher in order combine Science Learning with English Language Instruction, according to the Content and Language integrated learning (CLIL). In this way both scientific literacy and English fluency are promoted. The learning sequence is appropriate for this method since all the DLOs and SERs are available in English'.
p. 2	The following points were added to the STEM content session: 'Descriptive statistics (simple measures, indices, charts, and graphs) as a means of analyzing presenting qualitative and quantitative scientific data'. 'The process of an authentic scientific research and issues concerning the trustworthiness, biases, and misinterpretation of data'.
p. 4	The following passage was added in the definition of 'inquiry based learning': '…In structured inquiry students are given the research question to-be-answered, as well as detailed step-by-step guidance of the entire process of inquiry. In guided inquiry student are only given the research question to-be-answered and the decision-making processes about the research procedure are set up to them'.
p. 4	The following learning competences were added: 'Public health literacy', 'health disparities', 'health policies'
p. 5	The following points were added in the 'Prerequisite knowledge and skills': Basic competencies of finding, comparing and evaluating pieces of information in texts. Intermediate (or at least limited) fluency in English in case that DLOs and SERs other than the ones of the PAFSE repository are used.
p.7	The last point of the 'Teacher professional development actions' session was modified from 'The utilization of the scenario's digital learning objects in the inquiry-based learning process' into 'Inquiry-based-learning contextualization of the scenario's digital learning objects (structured inquiry, guided inquiry, case study, argumentation, problem solving)'.
p. 7	Addition of the following Digital Learning Object and link: *'Concept map tool* http://photodentro.pafse.eu/handle/8586/32?&locale=en'.
p. 7-8	Addition of the links of the DLOs II, III and IV 'http://photodentro.pafse.eu/handle/8586/170' 'http://photodentro.pafse.eu/handle/8586/239' 'http://photodentro.pafse.eu/handle/8586/240'
p.7-8	DLOs I, II, III and IV were renamed: 'Concept mapping about the social determinants of an epidemic' 'Map concerning the origin of communicable diseases' 'Social determinants of epidemics' 'Health-related decision-making during an epidemic'
p. 8	The following sentence was removed: 'The DLO environment also provides short explanations for specific terminology used, like a small-scale glossary'
p. 8	SER I was renamed:

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	'Conceptions about the social determinants of health and the origin of diseases'
p. 9	The phrase '(in Greek)' in SER VIII was removed.
p. 9	SER XI was replaced with the following one: 'E-me platform H5P tools for the school project H5P tools of the e-me platform (https://e-me4all.eu/). By choosing 'e-me content' students can use the 'Questionnaire' tool to create the questionnaire, the 'Graph' tool to handle and present the statistical data, and the 'Accordion' tool to form the final research report'.
p. 9	Addition of the note: 'Some educational activities have been framed … optional homework for students interested'
p. 9	Addition of the learning objectives table under the '1st teaching hour'.
p. 9-10	Addition of the following texts under the '1st teaching hour': 'The teacher could also use … in groups'. 'If students are already familiar … might be written on paper'. 'The questionnaire completion and the graphic depiction … of the necessary guidance'.
p. 10	Addition of the learning objectives table under the '2nd teaching hour'.
p. 10-11	Addition of the following texts and phrases under the '2nd teaching hour': '…seen in the framework of 'One Health' approach…'. '… in order to answer short scientific questions…'. 'Each group is responsible … to be respected'. 'The group brainstorming … at least once'.
p. 10-11	The following minor changes were made under the '2nd teaching hour': The phrases 'Creutzfeldt Jakob prion' and 'malaria' were removed. The phrase 'vericella' was added.
p. 11	The following passages were set into frames indicating being optional: 'Afterwards, students focus on recent cases … non-developed natural areas'. 'As a final recapitulation … with a projector machine'.
p. 11-12	Addition of the learning objectives table under the '3rd-4th teaching hours'.
p. 12-13	Addition of the following texts and phrases under the '3rd-4th teaching hours': '…The critical appraisal of each source is guided by a central research question which students are told to answer according to the critical reading of the sources'. '…After studying each source, or the sum of them, a class discussion should be done to compare students' conclusions and comment on them …'. 'In case there are not computers … while the groups work on this task'. 'If the study tasks of each source … on one single infographic to save time'. 'If time is not sufficient … higher difficulty level than SER VII'.
p. 13	The following passage was set into a frame indicating being optional: 'Academic text SER VII … intrinsic features of all health crises'.
p. 14	Addition of the learning objectives table under the '5th-6th teaching hours'.
p. 15	The phrase 'The number of sentences are suggested to be about 10-15' is changed to The number of sentences is suggested to be about 7 to 10'.
p. 15	The following passage was set into a frame indicating being optional: 'Afterwards, students are given some hypothetical cases … by each pair of students'.
p. 14-16	Addition of the following texts and phrases under the '5th-6th teaching hours': 'If the teacher thinks being more appropriate … of the previous lesson'. 'The role game aims to getting … their competences, skills, and experiences'. 'The classroom discussion and idea exchange phase … a general context of awareness'.

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	'The entire three-part role game … could be used, instead'.
p. 16	Addition of the learning objectives table under the '7th-8h teaching hours'.
p. 16-17	Addition of the following texts and phrases under the '7th-8th teaching hours': 'The entire research project follows the phases … from physical sciences. '…The exact research questions are defined and formulated by students themselves based on their personal interests …'. '…Each group of students is preferable comprised by 4 students, and is responsible for the study of one or two research questions, and the development and formulation of the questions for the relevant questionnaire section'. '…examining only one issue per question…'. '… (qualitative data)…' '…It is important to clarify the different types of data (qualitative and quantitative) to students, and their different ways of collection, and their different function in social research, which means that qualitative data are more appropriate for free expression, and quantitative data are more appropriate for the organized study of a large amount of data'. 'If the teacher thinks that already formulated questions … would not practice their critical thinking skills'. 'Each questionnaire section … in each section of the final questionnaire'. 'The fill-in of the questionnaires … only a sample of them could by analyzed'.
p. 17	The phrase 'Google Forms' was replaced by the phrase 'the tools of the e-me platform'
p. 17	Addition of the learning objectives table under the '9th-10th teaching hours'.
p. 17	The following passage was removed: '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'
p. 18	Addition of the phrase 'bar charts':
p. 18	Addition of the following texts and phrases under the '9th-10th teaching hours': ' … At this point, a revision or introduction of some necessary elements regarding statistical analysis and graphs creation might be needed. SER XI could be used to create graphs and charts'. 'The data analysis should include …to the other members to check'. 'The section of conclusion making … very simple ideas are welcome'.
p. 18	Addition of the learning objectives table under the '11th-12th teaching hours'.
p. 18-19	The following passages were set into a frame indicating being optional: 'The discussion might focus … impersonal and flawless character'. 'If the quality of students' work … student academic conference or journal'.
p. 19	Addition of the following text under the '11th-12th teaching hours': ' The final research report ought to be … agreed by the entire classroom'.
p. 19	The phrase 'SER XI can be used' was added.
p. 19	The entire session 'Short version of the scenario' was added. The passage 'The initial (extended version) … are the following ones:' was added The table was added.
p. 21-23	The following references were added and alphabetically ordered: Bechraki, E., Mavrikaki, E., Gialamas, V., & Galanaki, E. (2022). Development and validation of an instrument for the health literacy assessment of secondary school students (HeLiASeSS). HealthEducation, 122(6), 678-699. Braveman, P. (2006). Health disparities and health equity: concepts and measurement. *Annual Review Public Health*, 27, 167-194. Braveman, P., Egerter, S., & Williams, D. R. (2011). The social determinants of health:

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p. 22	The following reference was removed: Matthews, M. R. (2007). Models in science and in science education: An introduction. *Science & education*, *16*(7), 647-652.

Scenario Title: Social determinants of health during an epidemic/pandemic outbreak – Middle school (Junior high school) version

Page Number	Modification
General Structure	The pilot version of the scenario was modified in order to make two different versions of the scenarios: one for middle/junior high school grades (K7-9), and one for high/senior high school grades (K10-12). The modification of the high school version is shown here.
Throughout the scenario	Spelling and grammar errors were corrected. Scientific terms where replaced in some cases with more widely used terms (e.g. 'didactic' was replaced with 'teaching' in p. 3).
Throughout the scenario	Several activities were characterized as 'optional'.
Throughout the scenario	Several activities were outlined with dotted frames to show that their enactment is optional.
p.1	The clarification 'Middle school (Junior high school) version' was added in the title.
p.1	'University of Ioannina, Ioannina, Greece' was replaced by 'The Educational Approaches to Virtual Reality Laboratory (EARTH Lab), Department of Primary Education, University of Ioannina, Ioannina, Greece'.
p.1	The following points were added to the 'scientific content and its relevance to Public Health Education' session: 'Social and health disparities pose a serious issue in public health promotion. Students have to be aware of this problem in order to evolve to active citizens'. 'The notion of health is contextualized in authentic societal settings (health policies), and an authentic way of health-related decision-making, including emotional, social, economic, and ethical factors'. 'Some environmental determinant of health are approached, and more particularly, the major problem of the origin of Emerging Infectious Diseases, in the context of the One Health Approach'.
p.1	The text of the 'Estimated duration & relevant subject' session was modified from '12 teaching hours, organized in continuous two-hour periods if possible. Designed for Biology, Science or Social Science classes of K7-9 grades' into '12 teaching hours

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	(extended version of the scenario), organized in continuous two-hour periods if possible. 6 teaching hours (short version of the scenario). Designed for Biology, Science, Health Science, or Social Science classes of middle school (junior high school) grades (K9-11 grades). The Biology (or Science, or Health Science, or Social Science) teacher could cooperate with the English language teacher in order to combine Science Learning with English Language Instruction, according to the Content and Language integrated learning (CLIL). In this way both scientific literacy and English fluency are promoted. The learning sequence is appropriate for this method since all the DLOs and SERs are available in English'.
p. 2	The following points were added to the STEM content session: 'Descriptive statistics (simple measures, indices, charts, and graphs) as a means of analyzing presenting qualitative and quantitative scientific data'. 'The process of an authentic scientific research and issues concerning the trustworthiness, biases, and misinterpretation of data'.
p. 4	The following passage was added in the definition of 'inquiry based learning': '…In structured inquiry students are given the research question to-be-answered, as well as detailed step-by-step guidance of the entire process of inquiry. In guided inquiry student are only given the research question to-be-answered and the decision-making processes about the research procedure are set up to them'.
p. 4	The following learning competences were added: 'Public health literacy', 'health disparities', 'health policies'
p. 5	The following points were added in the 'Prerequisite knowledge and skills': Basic competencies of finding, comparing and evaluating pieces of information in texts. Intermediate (or at least limited) fluency in English in case that DLOs and SERs other than the ones of the PAFSE repository are used.
p.7	The last point of the 'Teacher professional development actions' session was modified from 'The utilization of the scenario's digital learning objects in the inquiry-based learning process' into 'Inquiry-based-learning contextualization of the scenario's digital learning objects (structured inquiry, guided inquiry, case study, argumentation, problem solving)'.
p. 7	Addition of the following Digital Learning Object and link: *'Concept map tool* http://photodentro.pafse.eu/handle/8586/32?&locale=en'.
p. 7-8	Addition of the links of the DLOs II, III and IV 'http://photodentro.pafse.eu/handle/8586/170' 'http://photodentro.pafse.eu/handle/8586/239' 'http://photodentro.pafse.eu/handle/8586/240'
p.7-8	DLOs I, II, III and IV were renamed: 'Concept mapping about the social determinants of an epidemic' 'Map concerning the origin of communicable diseases' 'Social determinants of epidemics' 'Health-related decision-making during an epidemic'
p. 8	The following sentence was removed: 'The DLO environment also provides short explanations for specific terminology used, like a small-scale glossary'
p. 8	The SER I was renamed: 'Conceptions about the social determinants of health and the origin of diseases'
p. 8-9	SERs IV and IX, their links, as well as the texts below, were removed: 'Short news excerpt regarding health disparities during the COVID-19 pandemic in the

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	USA, related to nationality/race and working conditions'. 'Educational YouTube video about the consequences of social disparities and discrimination on the impact the COVID-19 pandemic had on different social groups'.
p. 8-9	The number of some SERs has been changed as shown below: SER IV → removed SER V → SER IV SER VI → SER V SER VII →SER VI SER VIII→SER VII SER IX → removed SER X→SER VIII SER XI→ SER IX
p. 9	The phrase '(in Greek)' in SER VIII was removed.
p. 9	The SER XI was replaced with the following one: 'E-me platform H5P tools for the school project H5P tools of the e-me platform (https://e-me4all.eu/). By choosing 'e-me content' students can use the 'Questionnaire' tool to create the questionnaire, the 'Graph' tool to handle and present the statistical data, and the 'Accordion' tool to form the final research report'.
p. 9	Addition of the note: 'Some educational activities have been framed … optional homework for students interested'
p. 9	Addition of the learning objectives table under the '1st teaching hour'.
p. 9-10	Addition of the following texts under the '1st teaching hour': 'The teacher could also use … in groups'. 'If students are already familiar … might be written on paper'. 'The questionnaire completion and the graphic depiction … of the necessary guidance'.
p. 9	The phrase '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' is replaced by the phrase 'in the form of a mind map. Mind map are easier to be made and understood for middle school students than concept maps, especially if they have limited previous experience with concept maps. Advanced students can easily turn their mind maps into concept maps by writing verbs above the linkages'.
p. 9	The phrase 'concept mapping tool' has been replaced by the phrase 'mind mapping tool'. The phrase 'concept or mind map' has been replaced by the phrase 'mind map'.
p. 10	Addition of the learning objectives table under the '2nd teaching hour'.
p. 10-11	Addition of the following texts and phrases under the '2nd teaching hour': '…seen in the framework of 'One Health' approach…'. '… in order to answer short scientific questions…'. 'Each group is responsible … to be respected'. 'The group brainstorming … at least once'.
p. 10-11	The following minor changes were made under the '2nd teaching hour': The phrases 'Creutzfeldt Jakob prion' and 'malaria' were removed. The phrase 'vericella' was added.
p. 11	The following passages were set into frames indicating being optional: 'Afterwards, students focus on recent cases … non-developed natural areas'. 'As a final recapitulation … with a projector machine'.
p. 11	Addition of the learning objectives table under the '3rd-4th teaching hours'.

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p. 12	The passage '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' was replaced with 'The first video of DLO III will not be used, because of the high level of English fluency needed. Instead of watching the video, students are engaged in an introductory classroom discussion with the following topic'.
p. 12-13	The passage 'five sources of educational material' is replaced by 'four sources of educational material'. The phrase 'SER V' was replaced by 'SER IV'. The phrase 'SER VI' was replaced by 'SER V'. The phrase 'SER VII' was replaced by 'SER VI'. The phrase 'SER VIII' was replaced by 'SER VII'.
p. 12-13	The following passages were set into frames indicating being optional: 'Academic text SER VII … intrinsic features of all health crises'. 'Students have studied about health inequities … among European states'.
p. 12-13	The following passages were removed: 'They, also, complement other possible parameters leading to health inequities and are asked to consider whether some of these parameters affect one another'. 'Students are given two hypothetical cases of citizens and try to analyze, with the aid of worksheets, the health inequities they would face during an epidemic outbreak similar to 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'. '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 test whether a correlation of these indices with health accessibility, life expectancy and self-reported health condition exists'.
p. 12-13	Addition of the following texts and phrases under the '3rd-4th teaching hours': '…The critical appraisal of each source is guided by a central research question which students are told to answer according to the critical reading of the sources'. '…After studying each source, or the sum of them, a class discussion should be done to compare students' conclusions and comment on them …'. 'In case there are not computers … while the groups work on this task'. 'If the study tasks of each source … on one single infographic to save time'. 'If time is not sufficient … higher difficulty level than SER VII'. 'The study of either SER VI or DLO V … or communicable diseases, in general'.
p. 13-14	Addition of the learning objectives table under the '5th-6th teaching hours'.
p. 14-15	The phrase 'The educational videos SERs IX and X' has been replaced by the phrase 'The educational video SER VIII'. The phrase 'These are two educational videos' has been replaced by the phrase 'It is'. The phrase 'The number of sentences are suggested to be about 10-15' has been changed to The number of sentences is suggested to be about 7 to 10'.
p. 14-15	Addition of the following texts and phrases under the '5th-6th teaching hours': 'If the teacher thinks being more appropriate … of the previous lesson'. 'The role game aims to getting … their competences, skills, and experiences'. 'The classroom discussion and idea exchange phase … a general context of awareness'. 'The entire three-part role game … could be used, instead'.

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p. 14-15	The following passage was set into a frame indicating being optional: 'Afterwards, students are given some hypothetical cases … by each pair of students'.
p. 15-16	Addition of the learning objectives table under the '7^{th}-8^{h} teaching hours'.
p. 16	The following phrase was removed: 'Secondly, the questionnaire aims at the detection of health inequity issues and possible correlations to social factors'.
p. 16	The following passage was set into a frame indicating being optional: 'When every group has finished … with the first group'.
p. 16-17	Addition of the following texts and phrases under the '7^{th}-8^{th} teaching hours': 'The entire research project follows the phases … from physical sciences. '…The exact research questions are defined and formulated by students themselves based on their personal interests …'. '…Each group of students is preferable comprised by 4 students, and is responsible for the study of one or two research questions, and the development and formulation of the questions for the relevant questionnaire section'. '…examining only one issue per question…'. '… (qualitative data)…' '…It is important to clarify the different types of data (qualitative and quantitative) to students, and their different ways of collection, and their different function in social research, which means that qualitative data are more appropriate for free expression, and quantitative data are more appropriate for the organized study of a large amount of data'. 'If the teacher thinks that already formulated questions … would not practice their critical thinking skills'. 'Each questionnaire section … in each section of the final questionnaire'. 'The fill-in of the questionnaires … only a sample of them could by analyzed'.
p. 16-17	The phrase 'but the subsequent options regarding research methodology and conduct, data collection, analysis and interpretation, conclusion making, and communication, are set upon the students' was replaced by the phrase 'and the subsequent steps regarding research methodology and conduct, data collection, analysis and interpretation, conclusion making, and communication, are given by the teacher. However, the guidance is given in the form of general directions, principles, phases, and techniques, and not in the form of a step-by-step guide'. The phrase 'Students decide on the questionnaire sections, and they are divided in groups equal in number to the questionnaire sections' was replaced by the phrase 'the tools of the e-me platform'. The phrase 'responsible for the study of one or two research questions' was replaced by the phrase 'responsible for the study of one research question'. The phrase 'Google Forms' was replaced by the phrase 'the tools of the e-me platform'. The phrase 'SER XI' was replaced by the phrase 'SER IX'. The phrase 'the number of questionnaires might be about 15 to 30' was replaced by the phrase 'the number of questionnaires might be about 10 to 20'.
p. 17	Addition of the learning objectives table under the '9^{th}-10^{th} teaching hours'.
p. 17	The following passage was removed: 'If participation is low, the analysis of the questionnaires could begin normally at the 9^{th} teaching hour, but also be expanded for one extra teaching hour until a sufficient number of online questionnaires has been collected'
p. 17	Addition of the phrase 'bar charts'.
p. 17	The phrase 'e.g., 15 questionnaires' has been replaced by 'e.g. 8 questionnaires'.

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p. 17-18	Addition of the following texts and phrases under the ‘9th-10th teaching hours’: ‘At this point, a detailed course on the necessary elements of statistical analysis, graph creation revision or introduction of some necessary elements regarding statistical analysis and graphs creation is necessary. This introduction might include some of the following ones: the distinction of quantitative and qualitative data, the creation of histograms, bar charts, pie charts, and scatter plots, the calculation of absolute and relative frequencies, the calculation of mean, range, and media, and the identification of common or repetitive themes in qualitative data. SER IX, or some other relevant software, could be used to create graphs and charts’. ‘The data analysis should include … to the other members to check’. ‘The section of conclusion making … very simple ideas are welcome’.
p. 18	Addition of the learning objectives table under the ‘11th-12th teaching hours’.
p. 18	Addition of the following texts under the ‘11th-12th teaching hours’: ‘The teacher’s guidance is decisive during this process, since students tend to confuse results with conclusions. This distinction must be made quite clear. It is a very important in component of scientific literacy and scientific competencies since it illustrates the deep Nature of Science distinction between facts and assumptions’. ‘The final research report ought to be … agreed by the entire classroom’.
p. 18	The phrase ‘SER IX can be used’ was added.
p. 18-19	The following passages were set into a frame indicating being optional: ‘The discussion might focus … impersonal and flawless character’. ‘If the quality of students’ work … student academic conference or journal’.
p. 19-20	The entire session ‘Short version of the scenario’ was added. The passage ‘The initial (extended version) … are the following ones:’ was added The table was added.
p. 21-23	The following references were added and alphabetically ordered: Bechraki, E., Mavrikaki, E., Gialamas, V., & Galanaki, E. (2022). Development and validation of an instrument for the health literacy assessment of secondary school students (HeLiASeSS). HealthEducation, 122(6), 678-699. Braveman, P. (2006). Health disparities and health equity: concepts and measurement. *Annual Review Public Health*, 27, 167-194. Braveman, P., Egerter, S., & Williams, D. R. (2011). The social determinants of health: coming of age. *Annual review of public health*, 32(1), 381-398. Budd, J. W. (2004). Mind maps as classroom exercises. *The journal of economic education*, 35(1), 35-46. Bybee, R. W. (2014). The BSCS 5E instructional model: Personal reflections and contemporary implications*. Science and Children*, 51(8), 10-13. Chalkidis, D., Santos, C., & Mikropoulos T. A. (2022). Partnerships for Science Education: Public health education and awareness with digital technologies. *13th Conference of European Researchers in Didactics of Biology (ERIDOB)*, 29th August -2nd September 2022, Nicosia, Cyprus. Constantinou, C. P., Tsivitanidou, O. E., & Rybska, E. (2018). What is inquiry-based science teaching and learning?. In *Professional development for inquiry-based science teaching and learning* (pp. 1-23). Springer, Cham. Creswell, J. W. (2011). *Educational Research. Planning, conducting and evaluating quantitative and qualitative research* (Fourth Edition). Pearson. Eyler, J. (2009). The power of experiential education. *Liberal education*, 95(4), 24-31. Gaintatzis, P., Chalkidis, D., Iatraki, G., Mikropoulos, T. A., Megalou, E., Santos, C. (2023). Designing Digital Learning Objects for Public Health. *4th Panhellenic*

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p. 22	The following reference was removed: Matthews, M. R. (2007). Models in science and in science education: An introduction. *Science & education*, *16*(7), 647-652.

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Scenario Title: Function of vaccines, vaccine hesitancy and misinformation – High school (Senior high school) version

Page Number	Modification
General Structure	The pilot version of the scenario 'Function of vaccines, vaccine hesitancy and misinformation' was modified in order to make two different versions of the scenarios: one for middle/junior high school grades (K7-9), and one for high/senior high school grades (K10-12). The modifications of the high school version are shown here.
Throughout the scenario	Spelling and grammar errors were corrected. Scientific terms were replaced with more widely used terms (e.g. 'didactic' was replaced with 'teaching' in p. 4), in some cases.
Throughout the scenario	Several activities were outlined with dotted frames to show that their enactment is optional.
p.1	The clarification 'High school (Senior high school) version' was added in the title.
p. 1	The word 'vaccination hesitancy' was changed to 'vaccine hesitancy' in the title of the scenario.
p.1	'University of Ioannina, Ioannina, Greece' was replaced by 'The Educational Approaches to Virtual Reality Laboratory (EARTH Lab), Department of Primary Education, University of Ioannina, Ioannina, Greece'.
p.2	The text of the 'Estimated duration & relevant subjects' session was modified from '14 teaching hours organized in continuous two-hour periods if possible. Designed for Biology classes (or Science classes in general) of K7-9 grades.' into '14 teaching hours (extended version of the scenario) organized in continuous two-hour periods if possible. 10 teaching hours (short version of the scenario). Designed for Biology or Health Sciences classes of high school (senior high school) grades (K10-12 grades). The scenario might also be applicable for a unified Science syllabus. The Biology (or Health Science, or Science) teacher could cooperate with the English language teacher in order to combine Science Learning with English Language Instruction, according to the Content and Language integrated learning (CLIL). In this way both scientific literacy and English fluency are promoted. The learning sequence is appropriate for this method since all the DLOs and SERs are available in English'.
p. 2	The following passage was added in the 'STEM content' session: ' … (science communication)'.
p. 2-3	The following passages were added in the 'Content glossary' session: '… or specific immunity…'. '…or nonspecific immunity…'.
p. 3	The word 'recombined' was changed to 'recombinant'.
p. 5	The following passage was added in the definition of 'inquiry based learning': '…In structured inquiry students are given the research question to-be-answered, as well as detailed step-by-step guidance of the entire process of inquiry. In guided inquiry student are only given the research question to-be-answered and the decision-making processes about the research procedure are set up to them'.
p. 5	The following definition was added in the 'Pedagogical glossary' session, and alphabetically ordered: **'Problem solving**: The problem solving approach includes students groups practicing higher thinking skills and making decisions in to analyze a given problem and propose solutions to it. At first, the problem settings are described to students along with the desirable aim, and some basic limitations. Each groups analyzes the problem and comes up with as more and as diverse solutions possible (creative thinking), and then evaluates these ideas (critical thinking) through group discussions, pros and cons

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	comparisons, assessment according to criteria, pilot tests, tests, or other ways, and come down to a final proposed solution, as detailed as possible. After testing the proposed solution, or getting feedback on it, the group might have to repeat the steps of improve the solution’.
p. 5	The following learning goal was added: ‘Science communication and journalism’, ‘recombinant vaccines’.
p. 6	The following points was added in the ‘Prerequisite knowledge and skills’: Intermediate, or at least limited, fluency in English in case that DLOs and SERs other than the ones of the PAFSE repository are used.
p. 6	The following research project topic was removed: ‘What types of vaccines exist and on what occasions is each vaccine type preferable?’
p. 8-9	The following points and passages were added in the ‘Teacher professional development actions’: ‘…and recognizing…’. ‘Ways to handle controversial socioscientific issues in the classroom’.
p. 8	The phrase ‘The educational integration and utilization of digital educational resources’ was changed to ‘The utilization of the scenario’s digital learning objects in the inquiry-based learning process’ into ‘Inquiry-based-learning contextualization of the scenario’s digital learning objects (structured inquiry, guided inquiry, case study, argumentation, problem solving)
p. 9	Addition of the following links to DLOs I, II, III, IV, V, VI, VIII, and IX: ‘http://photodentro.pafse.eu/handle/8586/50’. ‘http://photodentro.pafse.eu/handle/8586/242’. ‘http://photodentro.pafse.eu/handle/8586/148’. ‘http://photodentro.pafse.eu/handle/8586/172’. ‘http://photodentro.pafse.eu/handle/8586/157’. ‘http://photodentro.pafse.eu/handle/8586/171’. ‘http://photodentro.pafse.eu/handle/8586/160’. ‘http://photodentro.pafse.eu/handle/8586/241’.
p. 9	The DLOs II, III, IV, V, VII, and IX were renamed with the following names: ‘Mechanisms of specific immune response’. ‘Concept map about the immune response’. ‘Function of vaccine types’. ‘Concept map about vaccines’. ‘Vaccine efficacies and adverse effects’. ‘Information and misinformation about vaccines’.
p. 9	DLO VII was added, along with its link, and the following text: ‘*‘Timeline of smallpox* *http://photodentro.pafse.eu/handle/8586/243* Timeline of the evolution and eradication of smallpox, including ancient references to the disease, historical epidemics and pandemics, the development of the first vaccines against it, the implementation of mass vaccination programmes, and the total eradication of the disease’.
p. 9-10	The following DLOs were renumbered as below: DLO VII → new DLO DLO VII → DLO VIII DLO VIII → DLO IX DLO IX → DLO X DLO X → DLO XI DLO XI → DLO XII

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	DLO XII → DLO XIII DLO XIII → DLO XIV
p. 10	The link and the title of SER I were added: 'Conceptions about microbes, immunity, and vaccines http://photodentro.pafse.eu/handle/8586/173'
p. 10-11	The titles of SERs II, III, IV, V, VI, VII, VIII, IX, X, XI, XII, XIII, XIV, XV, and XVI were added: 'The importance of vaccination' 'Polio eradication' 'Vaccination against the pneumoniococcus' 'Main categories of pathogens' 'Diversity of pathogens' 'Microorganism scale' 'Bacterial diversity' 'Macrophage phagocytosis' 'How vaccines work' 'Vaccines against COVID-19' 'What herd immunity is' 'World's deadliest pandemics' 'Word frequency over time' 'Measles outbreaks and vaccine coverage' 'Misinformation about vaccine adverse effects'
p. 11	SER XVII was added, as well its link and the following text: 'E-me platform H5P tools for the school project H5P tools of the e-me platform (https://e-me4all.eu/). By choosing 'e-me content' students can use the 'Course Presentation' tool to create an interactive and multimodal presentation promoting vaccination, including texts, images, videos, short questions, etc, for the health promotion campaign, and the 'Interactive Book' to write an interactive and multimodal guide against vaccination, having the same technical potential, as well'.
p. 11-12	Addition of the note: 'Some educational activities have been framed … optional homework for students interested'
p. 12	Addition of the learning objectives table under the '1st teaching hour'.
p. 12	The phrase '30 close-ended questions' has been changed to '15 close-ended questions'. The phrase 'DLO IX' has been changed to 'DLO X'.
p. 12-13	Addition of the following texts under the '1st teaching hour': 'The suggested educational resources … distributed in print'. 'In order to have students use … could be distributed'.
p. 13	Addition of the learning objectives table under the '2nd teaching hour'.
p. 13-14	Addition of the following texts under the '2nd teaching hour': 'Infographic SER VI might be unsuitable or too time-consuming for certain students or classes because of the large load of information it has, or the advanced use of English (including advanced scientific terms)'. 'Students do not have to use the explanatory texts … pieces of information'.
p. 13	The following passage was set into a frame indicating being optional: 'Afterwards, students handle the visualization … optical microscope are explained'.
p. 13-14	The phrase 'DLO X' has been changed to 'DLO XI'.

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p. 13	The following passage was removed: '…and their life cycles…'.
p. 14	Addition of the learning objectives table under the '3rd teaching hour'.
p. 14-15	Addition of the following texts and passages under the '3rd teaching hour': ' … or specific …' 'The immunity concepts and processes … with the entire immune system'. 'It is suggested not to focus on the names of the immune cell types during the instruction, but to put emphasis on their roles, instead. Specific mentions must be made on the function of the memory cells and the antibodies'. 'A graph showing primary and … quantity of antibodies, therefore'. 'The concept map is complex … during the instruction'.
p. 15	The following passage was set into a frame indicating being optional: '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'.
p. 15	Addition of the learning objectives table under the '4th teaching hour'.
p. 16	The following passages were set into frames indicating being optional: 'The group of students present … 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'.
p. 16-17	Addition of the following texts and passages under the '4th teaching hour': '…some of which may be utilized during the lesson…'. 'The pathogen cases above … argue on their choices'. 'The video about the COVID-19 vaccines … instead of the video'. 'The concept map is complex … during the instruction'.
p. 17	Addition of the learning objectives table under the '5th teaching hour'.
p. 17-18	Addition of the following texts and passages under the '5th teaching hour': 'The distinction between dependent and independent … to get comparable results'. 'The activities of this hour … answering the to the initial question'. 'The activity above can, also … the same natural phenomenon'. 'In order to make the graph … the phenomenon of herd immunity'. 'If students have difficulties in making graphs, some relevant software can be used, providing the teacher thinks it is a more appropriate approach'. '…At some cases the achievement of herd immunity is impossible, and that is a point to be discovered by students'. '…diphtheria…'.
p. 18	The following passage was set into a frame indicating being optional: 'Then, students are assigned … their findings in the classroom'.
p. 18	The phrase 'DLO XI' was changed to 'DLO XII'.
p. 18	The following words were removed 'seasonal flu', 'H1N1 Influenza', 'polio', 'mumps'.
p. 18-19	Addition of the learning objectives table under the '6th teaching hour'.
p. 19	Addition of the following texts and passages under the '6th teaching hour': 'The activity above follows the process …place for conclusion making'. 'The use of SER XIV … in order to save time'. '…DLO VII can be used to follow the history of smallpox from its first accounts, through the deadliest pandemics, and finally up to the complete eradication'. 'The use of the SER XV about the re-emergence of measles outbreaks can be done by the teacher in a form of demonstration with the use of a projector machine, and

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	students can draw the conclusions from it'.
p. 19	The phrase 'DLO XII' was changed to 'DLO XIII'. The phrase 'DLO IX' was changed to 'DLO X'.
p. 19-20	Addition of the learning objectives table under the '7th teaching hour'.
p. 20	The following passages were set into frames indicating being optional: 'The video SER XVI … adverse effects is raised'. 'Students are shortly engaged … vaccine efficacy differently'.
p. 20	Addition of the following texts and passages under the '7th teaching hour': 'Instead of showing the video … or other relevant issues'. '…tetanus, varicella…' '…meningococcal disease…' 'The use of SER XIV can be done in a form of demonstration with the use of a projector machine'.
p. 20	The following words were removed 'H1N1 Influenza', 'mumps', 'rubella', 'pneumoniococcus', 'hepatitis B'.
p. 20	The phrase 'DLO VII' was changed to 'DLO VIII'. The phrase 'DLO XIII' was changed to 'DLO XIV'.
p. 21	Addition of the learning objectives table under the '8th teaching hour'.
p. 21	Addition of the following texts under the '8th teaching hour': 'There might be the need … criteria to the following texts'. 'If time is limited … classroom discussion part'.
p. 21	The phrase 'DLO VIII' was changed to 'DLO IX'.
p. 21-22	Addition of the learning objectives table under the '9th-10th teaching hours'.
p. 22	Addition of the following texts and passages under the '9th -10th teaching hours': '…(SER XVII could be used)…'. '…(SER XVII could be used)…'. 'The suggested software for the school project … could be used as well'. 'If the teacher thinks is more appropriate, only one project option out of the two could by done by all the students'.
p. 22-23	Addition of the learning objectives table under the '11th-14th teaching hours'.
p. 23	Addition of the following texts and passages under the '11th -14th teaching hours': 'The improvement of the developed material … their competencies'. '…(DLO I)…'
p. 23-24	The entire session 'Short version of the scenario' was added. The passage 'The initial (extended version) … are the following ones:' was added The table was added.
p. 26-28	The following references were added and ordered alphabetically: Abel, T., & McQueen, D. (2020). Critical health literacy and the COVID-19 crisis. *Health promotion international*, 35(6), 1612-1613. Bechraki, E., Mavrikaki, E., Gialamas, V., & Galanaki, E. (2022). Development and validation of an instrument for the health literacy assessment of secondary school students (HeLiASeSS). *Health Education,* 122(6), 678-699. Bin, S. N., & Kamel, M. N. B. (2021). COVID-19 misinformation online and health literacy: a brief overview. *International journal of environmental research and public health*, 18, 8091. Bonoti, F., Christidou, V., & Papadopoulou, P. (2022). Children's conceptions of coronavirus. *Public Understanding of Science*, 31(1), 35-52. Bybee, R. W. (2014). The BSCS 5E instructional model: Personal reflections and contemporary implications. *Science and Children*, 51(8), 10-13. Byrne, J., & Grace, M. (2010). Using a concept mapping tool with a photograph

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Scenario Title: Function of vaccines, vaccine hesitancy and misinformation – Middle school (Junior high school) version

Page Number	**Modification**
General Structure	The pilot version of the scenario ‘Function of vaccines, vaccine hesitancy and misinformation’ was modified in order to make two different versions of the scenarios: one for middle/junior high school grades (K7-9), and one for high/senior high school grades (K10-12). The modifications of the middle school version are shown here.
Throughout the scenario	Spelling and grammar errors were corrected. Scientific terms were replaced with more widely used terms (e.g. ‘didactic’ was replaced with ‘teaching’ in p. 4), in some cases.
Throughout the scenario	Several activities were outlined with dotted frames to show that their enactment is optional.
Throughout the scenario	The duration of the scenario was downsized.
p.1	The clarification ‘Middle school (Junior high school) version’ was added in the title.
p. 1	The word ‘vaccination hesitancy’ was changed to ‘vaccine hesitancy’ in the title of the scenario.
p.1	‘University of Ioannina, Ioannina, Greece’ was replaced by ‘The Educational Approaches to Virtual Reality Laboratory (EARTH Lab), Department of Primary Education, University of Ioannina, Ioannina, Greece’.
p.2	The text of the ‘Estimated duration & relevant subjects’ session was modified from ‘14

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	teaching hours organized in continuous two-hour periods if possible. Designed for Biology classes (or Science classes in general) of K7-9 grades.' into '12 teaching hours (extended version of the scenario) organized in continuous two-hour periods if possible. 8 teaching hours (short version of the scenario). Designed for Biology or Health Sciences classes of high school (senior high school) grades (K7-9 grades). The scenario might also be applicable for a unified Science syllabus. The Biology (or Health Science, or Science) teacher could cooperate with the English language teacher in order to combine Science Learning with English Language Instruction, according to the Content and Language integrated learning (CLIL). In this way both scientific literacy and English fluency are promoted. The learning sequence is appropriate for this method since all the DLOs and SERs are available in English'.
p. 2	The following passage was added in the 'STEM content' session: ' … (science communication)'.
p. 2-3	The following passages were added in the 'Content glossary' session: '… or specific immunity…'. '…or nonspecific immunity…'.
p. 3	The word 'recombined' was changed to 'recombinant'.
p. 5	The following passage was added in the definition of 'inquiry based learning': '…In structured inquiry students are given the research question to-be-answered, as well as detailed step-by-step guidance of the entire process of inquiry. In guided inquiry student are only given the research question to-be-answered and the decision-making processes about the research procedure are set up to them'.
p. 5	The following definition was added in the 'Pedagogical glossary' session, and alphabetically ordered: **'Problem solving**: The problem solving approach includes students groups practicing higher thinking skills and making decisions in to analyze a given problem and propose solutions to it. At first, the problem settings are described to students along with the desirable aim, and some basic limitations. Each groups analyzes the problem and comes up with as more and as diverse solutions possible (creative thinking), and then evaluates these ideas (critical thinking) through group discussions, pros and cons comparisons, assessment according to criteria, pilot tests, tests, or other ways, and come down to a final proposed solution, as detailed as possible. After testing the proposed solution, or getting feedback on it, the group might have to repeat the steps of improve the solution'.
p. 5	The following learning goal was added: 'Science communication and journalism', 'recombinant vaccines'.
p. 6	The phrase '14th teaching hour' was changed to '12th teaching hour' in the 'Classroom organization requirements' session.
p. 6	The following points was added in the 'Prerequisite knowledge and skills': Intermediate, or at least limited, fluency in English in case that DLOs and SERs other than the ones of the PAFSE repository are used.
p. 6	The following research project topic was removed: 'What types of vaccines exist and on what occasions is each vaccine type preferable?'
p. 8-9	The following points and passages were added in the 'Teacher professional development actions': '…and recognizing…'. 'Ways to handle controversial socioscientific issues in the classroom'.
p. 8	The phrase 'The educational integration and utilization of digital educational resources' was changed to 'The utilization of the scenario's digital learning objects in the inquiry-based learning process' into 'Inquiry-based-learning contextualization of

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	the scenario's digital learning objects (structured inquiry, guided inquiry, case study, argumentation, problem solving)
p. 9	Addition of the following links to DLOs I, II, III, IV, V, VI, VIII, and IX: 'http://photodentro.pafse.eu/handle/8586/50'. 'http://photodentro.pafse.eu/handle/8586/242'. 'http://photodentro.pafse.eu/handle/8586/148'. 'http://photodentro.pafse.eu/handle/8586/172'. 'http://photodentro.pafse.eu/handle/8586/157'. 'http://photodentro.pafse.eu/handle/8586/171'. 'http://photodentro.pafse.eu/handle/8586/160'. 'http://photodentro.pafse.eu/handle/8586/241'.
p. 9	The DLOs II, III, IV, V, VII, and IX were renamed with the following names: 'Mechanisms of specific immune response'. 'Concept map about the immune response'. 'Function of vaccine types'. 'Concept map about vaccines'. 'Vaccine efficacies and adverse effects'. 'Information and misinformation about vaccines'.
p. 9	DLO VII was added, along with its link, and the following text: *'Timeline of smallpox* *http://photodentro.pafse.eu/handle/8586/243* Timeline of the evolution and eradication of smallpox, including ancient references to the disease, historical epidemics and pandemics, the development of the first vaccines against it, the implementation of mass vaccination programmes, and the total eradication of the disease'.
p. 10	DLOs XI and XIII were removed, along with their links and the explanatory texts below: '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'. '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'
p. 9-10	The following DLOs were renumbered as below: DLO VII → new DLO DLO VII → DLO VIII DLO VIII → DLO IX DLO IX → DLO X DLO X → DLO XI DLO XI → removed DLO XII → DLO XII DLO XIII → removed
p. 10	The link and the title of SER I were added: 'Conceptions about microbes, immunity, and vaccines http://photodentro.pafse.eu/handle/8586/173'
p. 10-11	The titles of SERs II, III, IV, V, VI, VII, VIII, IX, X, and XI were added: 'The importance of vaccination' 'Polio eradication' 'Vaccination against the pneumoniococcus'

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	'Microorganism scale' 'Macrophage phagocytosis' 'How vaccines work' 'Vaccines against COVID-19' 'What herd immunity is' 'Measles outbreaks and vaccine coverage' 'Misinformation about vaccine adverse effects'
p. 10-11	SERs V, VI, VIII, XIII, XIV were removed, along with their links and the explanatory texts below: 'Educational YouTube video by the educational channel Stile, presenting the main characteristics and function of the most important kinds of pathogens (bacteria, viruses, fungi)'. 'Educational infographic by National Geographic concisely presenting the main kinds of pathogens'. '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'. 'Infographic illustrating the deadliest pandemics in the history of humanity'. 'A Google service which shows graphically the frequency with which selected words or phrases appear in texts from 1800 up to 2019'.
p. 10-11	The following SERs were renumbered: SER V→ removed. SER VI→removed. SER VII→SER V. SER VIII→removed. SER IX→SER VI. SER X→SER VII. SER XI→SER VIII. SER XII→SER IX. SER XIII→removed. SER XIV→removed. SER XV→ SER X. SER XVI→SER XI.
p. 11	SER XII was added, as well its link and the following text: 'E-me platform H5P tools for the school project H5P tools of the e-me platform (https://e-me4all.eu/). By choosing 'e-me content' students can use the 'Course Presentation' tool to create an interactive and multimodal presentation promoting vaccination, including texts, images, videos, short questions, etc, for the health promotion campaign, and the 'Interactive Book' to write an interactive and multimodal guide against vaccination, having the same technical potential, as well'.
p. 11	Addition of the note: 'Some educational activities have been framed … optional homework for students interested'
p. 11	Addition of the learning objectives table under the '1st teaching hour'.
p. 11-12	The phrase '30 close-ended questions' has been changed to '15 close-ended questions'. The phrase 'DLO IX' has been changed to 'DLO X'.
p. 12	Addition of the following texts under the '1st teaching hour': 'The suggested educational resources … distributed in print'.

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	'In order to have students use … could be distributed'.
p. 12	Addition of the learning objectives table under the '2nd teaching hour'.
p. 12-13	Addition of the following texts and passages under the '2nd teaching hour': 'Students do not have to use the explanatory texts … pieces of information'. '…Some videos, images, or photographs showing bacteria can be used. The aim is to give student a brief idea on the cellular structure of bacteria, their shape, the existence of bacterial cell and DNA, and their way of reproduction'.
p. 12-13	The following passage was set into a frame indicating being optional: 'Afterwards, students handle the visualization … optical microscope are explained'.
p. 13	The following passages are removed: 'Students watch in pairs … each category of pathogens are also mentioned' '…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 …'. '…and their life cycles…'.
p. 13	The phrase 'DLO X' has been changed to 'DLO XI'.
p. 13	Addition of the learning objectives table under the '3rd teaching hour'.
p. 13-14	Addition of the following texts and passages under the '3rd teaching hour': ' … or specific …' 'The immunity concepts and processes … with the entire immune system'. 'It is suggested not to focus … secondary immune response'. 'A graph showing primary and … quantity of antibodies, therefore'. 'The concept map is complex … during the instruction'.
p. 14	The following passage was set into a frame indicating being optional: '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'.
p. 14	The phrase 'SER IX' was changed to 'SER VI'.
p. 14	Addition of the learning objectives table under the '4th teaching hour'.
p. 14-15	The phrase 'SER X' was changed to 'SER VII' The phrase 'SER XI' was changed to 'SER VIII'
p. 15-16	The following passages were set into frames indicating being optional: 'The group of students present … 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'.
p. 15-16	Addition of the following texts and passages under the '4th teaching hour': '…some of which may be utilized during the lesson…'. 'The pathogen cases above … argue on their choices'. 'The video about the COVID-19 vaccines … instead of the video'. 'The concept map is complex … during the instruction'.
p. 16	Addition of the learning objectives table under the '5th teaching hour'.
p. 16-17	Addition of the following texts and passages under the '5th teaching hour': 'The distinction between dependent and independent … to get comparable results'. 'The activities of this hour … answering the to the initial question'. '…They are given two infectivity values…'. 'In order to make the graph … the phenomenon of herd immunity'. 'If students have difficulties in making graphs, some relevant software can be used,

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	providing the teacher thinks it is a more appropriate approach'. '…At some cases the achievement of herd immunity is impossible, and that is a point to be discovered by students'. '…for further testing'. '…diphtheria…'.
p. 17	The following passages were set into a frame indicating being optional: 'Students use the DLO VI …compare the two curves'. 'Then, students are assigned … their findings in the classroom'.
p. 16-17	The phrase 'SER XII' was changed to 'SER IX'. The phrase 'DLO XI' was changed to 'DLO VI'.
p. 17	The following passages were removed: '…(with the R0 index. They are given two R0 values…' '…which offers them much more capabilities concerning parameter modification…'.
p. 17	The following words were removed 'seasonal flu', 'H1N1 Influenza', 'polio', 'mumps'.
p. 17-18	Addition of the learning objectives table under the '6th teaching hour'.
p. 18	Addition of the following texts and passages under the '6th teaching hour': 'The activity above follows the process …place for conclusion making'. '…They focus on the case of smallpox with the aid of DLO VII…'. 'The use of SER XIV … in order to save time'. '…DLO VII can be used to follow the history of smallpox from its first accounts, through the deadliest pandemics, and finally up to the complete eradication'.
p. 18	The phrase 'DLO IX' was changed to 'DLO X'. The phrase 'SER XV' was changed to 'SER X'.
p. 18	The following passage was set into a frame indicating being optional: Afterwards, students discuss in the classroom … up to the complete eradication.
p. 18	The following passages were removed: '…(infographic SER XIII)…'. '…At this point a simple search for the world smallpox in SER XIV shows that even references to the disease belong to the past …'.
p. 18-19	Addition of the learning objectives table under the '7th teaching hour'.
p. 19	The following passage was set into a frame indicating being optional: 'Then, students are asked whether ... repeatedly refuted since then'.
p. 19	Addition of the following texts and passages under the '7th teaching hour': 'Instead of showing the video … or other relevant issues'. '…tetanus, varicella…' '…meningococcal disease…'
p. 19	The following words were removed 'H1N1 Influenza', 'mumps', 'rubella', 'pneumoniococcus', 'hepatitis B'.
p. 19	The following passages were removed: 'Students are shortly engaged … the vaccine efficacy differently'. '…After expressing their estimations, they use SER XIV to find the appearance frequency of the word 'antivaccination' in texts from 1800 to 2019…'. '…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…'.
p. 19	The phrase 'SER XVI' was changed to 'SER XI'. The phrase 'DLO VII' was changed to 'DLO VIII'.
p. 19	Addition of the learning objectives table under the '8th teaching hour'.
p. 20	Addition of the following texts under the '8th teaching hour': 'There might be the need … criteria to the following texts'. 'If time is limited … classroom discussion part'.

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p. 20	The phrase 'DLO VIII' was changed to 'DLO IX'.
p. 20	Addition of the learning objectives table under the '9th-10th teaching hours'.
p. 21	Addition of the following texts and passages under the '9th -10th teaching hours': '…(SER XII could be used)…'. '…(SER XII could be used)…'. 'The suggested software for the school project … could be used as well'. 'If the teacher thinks is more appropriate, only one project option out of the two could by done by all the students'.
p. 21	The title '11th-14th teaching hours' was changed to '11th-12th teaching hours'.
p. 21	Addition of the learning objectives table under the '11th-12th teaching hours'.
p. 21-22	The following passages were removed: '…The teacher and the rest … of their material'. 'During the 13th teaching hour …communicated in the local media'
p. 22	Addition of the following passage under the '11th-12th teaching hours': '…(DLO I)…'
p. 22	The phrase '11th and 12th teaching hours' was changed to '11th and, partly, the 12th hour'. The phrase 'The 14th teaching hour' was changed to 'The rest of the 14th teaching hour'.
p. 22	The entire session 'Short version of the scenario' was added. The passage 'The initial (extended version) … are the following ones:' was added The table was added.
p. 22	The following passage was added: 'Basic principles of microbiology …might be omitted'.
p. 24-27	The following references were added and ordered alphabetically: Abel, T., & McQueen, D. (2020). Critical health literacy and the COVID-19 crisis. *Health promotion international*, 35(6), 1612-1613. Bechraki, E., Mavrikaki, E., Gialamas, V., & Galanaki, E. (2022). Development and validation of an instrument for the health literacy assessment of secondary school students (HeLiASeSS). *Health Education,* 122(6), 678-699. Bin, S. N., & Kamel, M. N. B. (2021). COVID-19 misinformation online and health literacy: a brief overview. *International journal of environmental research and public health*, 18, 8091. Bonoti, F., Christidou, V., & Papadopoulou, P. (2022). Children's conceptions of coronavirus. *Public Understanding of Science*, 31(1), 35-52. Bybee, R. W. (2014). The BSCS 5E instructional model: Personal reflections and contemporary implications. *Science and Children*, 51(8), 10-13. Byrne, J., & Grace, M. (2010). Using a concept mapping tool with a photograph association technique (CoMPAT) to elicit children's ideas about microbial activity. *International Journal of Science Education*, 32(4), 479-500. Chalkidis, D., Santos, C., & Mikropoulos T. A. (2022). Partnerships for Science Education: Public health education and awareness with digital technologies. *13th Conference of European Researchers in Didactics of Biology (ERIDOB),* 29th August -2nd September 2022. Nicosia, Cyprus. Chou, W. Y. S., & Budenz, A. (2020). Considering emotion in COVID-19 vaccine communication: addressing vaccine hesitancy and fostering vaccine confidence. *Health communication*, 35(14), 1718-1722. Constantinou, C. P., Tsivitanidou, O. E., & Rybska, E. (2018). What is inquiry-based science teaching and learning?. In *Professional development for inquiry-based science teaching and learning* (pp. 1-23). Springer, Cham.

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Partnerships for Science Education

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