Partnerships for Science Education

Project Number: 101006468

Project Acronym: PAFSE

Project title: Partnerships for Science Education

EDUCATIONAL SCENARIO

FUCTION OF VACCINES, VACCINE HESITANCY AND MISINFORMATION

(For Middle School classes – English version)

University of Ioannina

earth LAB Educational Approaches to Virtual Reality Technologies

AUGUST 2023

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

Scenario Title: Function of vaccines, vaccine hesitancy and misinformation (Middle school / Junior high school version)

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.
- 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

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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

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).

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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.

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.

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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 notion of social determinants of health in particular - and the participation in civic actions for the promotion of health.

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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

I. 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.

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II. Skills
a) General skills: Critical thinking, reflective thinking, critical reading, decision making, collaboration and communication within small groups, informative material designing skills, presentation skills.
b) Specific skills: Concept mapping, discussion about scientific topics, data-based decision-making on scientific issues, handling of digital scientific simulations, graph interpretation, graph creation, using mathematics within scientific contexts, variable handling in inquiry, hypothesis formulation and testing, data-driven conclusion making, reasoning about scientific topics, critical reading of scientific texts, critical appraisal of scientific information, detection of cases of scientific misinformation, skills concerning with communicating and presenting scientific topics.

III. Attitudes (Affective domain)
a) Attitudes and values: Adoption of a positive attitude towards science, acknowledgment of the value of scientific and technological progress, adoption of a positive attitude towards vaccination, appreciation of the value vaccination has for public health, acknowledgement of vaccination as a humanitarian practice for the common good (solidarity), development of trust towards science, development of a critical attitude towards scientific and health information.
b) Behaviours: Taking vaccination-related decisions driven by scientific evidence, participation in discussions concerning the vaccination necessity, getting vaccinated against infectious diseases, critical appraisal of health information in everyday life.

Classroom organization requirements
During the 1st teaching hour students work independently on computers. From the 2nd to 8th teaching hour students work in pairs, having one computer for each pair. The pairs often cooperate in some activities by two, shaping groups of four (2+2 technique). During the conduct of the projects (9th to 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

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

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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.).
- 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.

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Assessment activities

The assessment activities act complementarily to one another and aim at the close monitoring of the students' learning procedure. Some activities aim at formative and some others at summative assessment, some assess students in a quantitative and some others in a qualitative way, some aim at conceptual understandings, some at critical thinking skills, some at collaboration and communication skills and some others at affective domain assessment. They all contribute to having a multi-perspective view for each student. The teacher can omit or undermine some of the assessment activities if they think so. Some of the learning activities happen as the lesson takes place without special activities done or special assessment material designed (e.g., observation of students' participation or performance at question-and-answering).

- Initial assessment of students' initial conceptions and misconceptions via filling in a short questionnaire at the beginning of the learning sequence.
  Diagnostic quantitative assessment aiming at conceptual understanding.
- Formative assessment of students' worksheets during the entire learning sequence.
  Formative qualitative assessment aiming at conceptual understanding and inquiry skills.
- Formative student assessment through their participation in question-and-answering techniques and in class discussions during the entire learning sequence.
  Formative qualitative assessment aiming at conceptual understanding, inquiry and communication skills.
- Formative student assessment through their performance in the short quizzes and the concept maps in the 3^{rd} and 4^{th} 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 21^{st} century citizen (critical STEM literacy).
- Common misconceptions regarding microorganisms, immunity and vaccination as stated in scientific literature and ways of coping with them.

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- 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)

A. DLOs created specifically for the needs of the PAFSE project

I. *'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.

II. *'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.

III. *'Concept map about the immune response'*
http://photodentro.pafse.eu/handle/8586/148
Semi-structured concept map concerning the main points of immune response.

IV. *'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.

V. *'Concept map about vaccines'*
http://photodentro.pafse.eu/handle/8586/157
Semi-structured concept map concerning the main points of vaccine function and types.

VI. *'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.

VII. *'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.

VIII. *'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.

IX. *'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.

B. DLOs which have been retrieved from online resources

X. *'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.

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XI. *'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.

XII. *'Achievement of herd immunity over time'*
http://rocs.hu-berlin.de/D3/herd/
Dynamic simulation of herd immunity in the case of mass vaccination programs in children during many generations. The modification of the vaccination coverage and disease transmissibility is available.

Supplementary Educational Resources (SERs)

A. SERs created specifically for the needs of the PAFSE project

I. *'Conceptions about microbes, immunity, and vaccines'*
http://photodentro.pafse.eu/handle/8586/173
Questionnaire with 16 closed-ended questions concerning topics on microorganism biology, the function of the immune system and the vaccination process, about which misconceptions are common.

B. SERs which have been retrieved from online resources

II. *'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.

III. *'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.

IV. *'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.

V. *'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).

VI. *'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.

VII. *'How vaccines work'*
https://www.youtube.com/watch?v=-muIoWofsCE
Educational YouTube video by the channel Oxford VaccineGroup regarding the way vaccines work.

VIII. *'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.

IX. *'What herd immunity is'*
https://www.youtube.com/watch?v=XJFoOCmJsdg
Educational YouTube visualization video presenting the mechanism behind herd immunity.

X. *'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.

XI. *'Misinformation about vaccine adverse effects'*
https://www.youtube.com/watch?v=zBkVCpbNnkU

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Educational YouTube video by the channel Kurzgesagt about the degree of danger vaccine adverse effects have.

XII. *'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

- ➢ 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:
    i. The infographic (SER II) showing numerical data about the number of lives being saved every year thanks to vaccinations. Students are triggered to guess how many children lives are saved thanks to vaccinations every year and then see how close their estimation was to reality.
    ii. The interactive map (SER III) presenting the polio cases recorded during the previous year. The very restricted geographical area where polio still remains endemic is mentioned. This restriction has been achieved exclusively thanks to the administration of global mass vaccination programs over the last decades.

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iii. The infographic (SER IV) highlighting the importance of vaccination against pneumoniococcus with the aid of numerical data. Students might have heard of the pneumoniococcus vaccine, but have undermined its importance for the general population.

iv. The interactive map (DLO 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 structure ➢ Vague description of viruses reproduction ➢ Comparison and contrast of bacteria and viruses	➢ Recognition of visual representations 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 are introduced to the main pathogen categories (bacteria, viruses), their basic structural features, as well as nd the ways bacteria and viruses cause harm to the human body. Disease examples caused by each category of pathogens are also mentioned.
- Afterwards, students handle the visualization SER V to compare the scale of several microorganisms (bacterium, various viruses, yeast) to one another and to human cells. In this way a more realistic approach to the notion of scale of microorganisms is attempted and the reasons why viruses are endocytic parasites and are not visible with the optical microscope are explained.

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- Then, a short reference on bacteria takes place. The teacher briefly explains the main features of bacterial structure and morphology. 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 comprise 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	-

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

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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 words, what middle school students should memorize 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 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 contraditction 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

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- 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 visualization of the entire process of vaccine function from the time it gets introduced to the body until the immune response is triggered. Each category presents the part of the microorganism used, the mechanism in which the vaccine causes immune response, examples of vaccines from each type, and the main advantages and disadvantages of each type. The vaccine types presented are:
  i. Live-attenuated pathogen vaccines.
  ii. Inactivated pathogen vaccines.
  iii. Recombined microorganism vaccines / viral vector vaccines.
  iv. DNA vaccines.
  v. RNA vaccines.
  vi. Protein subunit vaccines.
  vii. Virus-like protein (VLP) vaccines
  viii. Toxoid vaccines.
- Students study the vaccine types and are assigned to choose which of them would propose for some hypothetical pathogens, explaining their rationale. There are probably more than appropriate choices for each pathogen. Some indicative pathogen cases, some of which may be utilized during the lesson, are the following ones:
  i. A highly infectious bacterium which produces harmful protein toxins.
  ii. A bacterium causing a very severe disease, and for that reason the development of the strongest immune response possible is preferable.
  iii. A vaccine against a very dangerous bacterium, which is especially targeted at people with a weakened immune system, like the cases of patients under immunosuppression (e.g. AIDS patients or patients with autoimmune diseases).
  iv. A highly infectious and dangerous bacterium with characteristic protein structures on its surface.
  v. A highly infectious and dangerous bacterium with well-studied genome and with characteristic protein structures on its surface, which are impossible to get isolated in the laboratory.
  vi. A very dangerous DNA virus with well-studied structure and genome.
  vii. A very dangerous RNA virus with well-studied structure and genome.
  viii. A mildly infectious virus but with very high transmissibility, and therefore it would be crucial to get strong immunity quickly, to prevent the spread of the disease.
  ix. A novel very dangerous virus which can be easily handled in the laboratory.
  x. A virus which mutates at a very high rate.
  xi. A very contagious and dangerous virus, which is a variant of an already existing virus with very low infectivity.
  xii. A mild virus during a vast epidemic outbreak, during which it is preferable to develop strong immunity as quick as possible (without repetitive vaccine doses).

The pathogen cases above are indicative. Each student group could work on 3-5 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 VIII 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 coverage of a population	➢ 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 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

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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 infectivity 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 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

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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 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

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		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, varicella, measles, meningococcal disease, polio, diphtheria, etc.). They observe the frequency and the kind of severe adverse effects, hospitalizations, 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 are explained that antivaccination movements are not something new, but 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 1980s. 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).

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- 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 to 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 8 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 3 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

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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 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. The option of the creation of informative material about the benefits of vaccination (second alternative) might be more appropriate for the majority of middle school students, on the grounds of their limited biology knowledge, critical text appraisal competencies, and misinformation detection competencies. Thus, a lot of them are still quite vulnerable to scientific misinformation.

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

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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 12th 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 8 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 (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. It highlights a non-biological topic (scientific misinformation) and the teacher could omit it, if they want to insist only on the biological phenomena. Yet, it provokes students' interest.
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

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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 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:

1. Doctors or medical professionals specialized in infectious diseases – They could discuss with students about the importance of vaccination and mass vaccination programs, the function of vaccines, the eradication of infectious diseases, their experience about people's attitudes towards vaccination, the debunking of anti-vaccination arguments and the re-emergence of past disease due to vaccine hesitancy.
2. Pediatricians – They could discuss with students about the necessity for mass vaccination programs for children, the re-emergence of certain diseases like measles, the attitudes of parents towards children vaccinations, the safety of vaccines and the misinformation about the MMR vaccine.
3. Pharmacists or biomedical experts – They could discuss with students about the different types of vaccines and their function, novel types of vaccines, the chemical constitution of a vaccine, the stages of vaccine development, testing and approval, state-of-the-art news concerning vaccine research, what COVID-19 has changed to vaccine research and development and the potential for a career in biomedical research.
4. Immunologists – They could discuss with students about the components and function of the human immune system, the way vaccines 'cheat' the human immune system, differences in immune response from different vaccine types, possible immunological complications due to vaccination (e.g., allergies, vaccination in immunosuppressed people) and what the future in vaccine development is.
5. Health or science journalists – They could discuss with students about the process of health and science journalism, the issue of the trustworthiness of sources, how fake news or misinformation can be detected and the sources a citizen should trust for information on science or health topics.
6. Health communicators or specialists in health outreach – They could discuss with students about health communication during COVID-19, the vast circulation of fake news and misinformation, their views towards the effective persuasion of vaccine hesitant people and the features that an effective health communication campaign should have.
7. Academics or university professors with relevant expertise.
8. Members of the PAFSE consortium with relevant expertise.

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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:

1. Medical museum – During this visit, students could probably come across items concerning historical cases of infectious diseases and their severity and how they have been eradicated over the decades thanks to vaccination.
2. Biomedical research laboratory – During this visit, students could see the actual work of biomedical scientists in drug development and testing, the apparatuses and techniques they use, and can discuss with them about their profession, the future of biomedical research and potential STEM careers in this domain.
3. Microbiology laboratory – During this visit, students could see different microbe specimens, cultivations, and microscope images, see common laboratory techniques in a microbiology laboratory, the ways and importance of disinfection and guidelines for the handling of biological material, and can discuss about STEM careers in this domain.
4. Mass vaccination center – During this visit, students could get informed about the importance of mass vaccination programs, maybe with emphasis on COVID-19 vaccination or children vaccination, get informed about the historic evolution of vaccination in the country, the difficulty of the implementation of vaccination programs, common myths concerning vaccines, the practical process of vaccination and the precautions taken guarantying the vaccines' safety.
5. Institution for health awareness, promotion or education – During this visit, students could take part in educational activities concerning the importance of vaccination, herd immunity and the threat of misinformation. They could also see authentic material of pro-vaccination campaigns.

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

Scenario topic: "Function of vaccines, vaccination hesitancy and misinformation"

A. 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
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

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	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 **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

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	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
B. 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 … 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	**Question 4.1:** I am able to gather and organize numerical data (e.g.,

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mathematical data	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 **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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C. 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
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

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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. 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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Partnerships for Science Education

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