NYMPHE EDUCATIONAL PROJECT – lessons at schools

Educational Stage: SECONDARY SCHOOLS (Pupils at the age of 12, having fundamentals of chemistry and biology, i.e. what is a chemical compound, what are chemical elements, what is a cell).
Subject: Biology, sustainability and citizenship education.
Duration: 2 hours lesson, with an interval.
Subject of the lesson: The invisible, but rich and colourful, world of microbes. Environmental microbial communities, their importance for our life and how we can exploit them for a more sustainable world.
Overall Objectives: To explain the basics of environmental microbiology and the concept of bioremediation/revitalization as a pollution mitigation strategy.
Specific Objectives: To explain the importance of bacteria to human lives and the environment and the exploitation of microbial consortia for bioremediation and sustainability.
Teaching Methods: Lecture, discussion, informative presentation, brainstorming, practical laboratory.
Forms of Work: Individual work, group work.
Attachments: Multimedia presentations with descriptions.
Teaching Aids: Multimedia presentations (accompanied by a video), presentation descriptions for teachers, and explanation of the experiment procedure.

Lesson Plan:

1. **Introduction + formalities (5 minutes)**
2. **Introduction to microbial world (15 min)**

   The first part of the lesson aims at getting students acquainted with the general microbial ecology aspects, the microbial world and its incredible biodiversity and importance. The discussion starts with a citation of Stewart Brandt “If you don’t like bacteria, you’re on the wrong planet”, to explain that microbes are the most ancient forms of life on our planet, they are more abundant, more biodiverse and more spread than humans, they are the number one colonizers of our planet. To raise curiosity in young students, examples of bacteria inhabiting inhospitable and hardly reachable corners of our planet are given, introducing the ability of bacteria to change visible aspects of the colonized places, such as the colour of snow or mud.

3. **Discussion (10 min)**

   Then, the teacher starts a discussion about the ability of bacteria to colonize inhospitable places bringing out examples of bacteria inhabiting places that were made inhospitable by anthropic activity, such as radiation-polluted sites, plastic wastes, or oil-polluted environments.

   Examples of questions for discussion to encourage critical thinking, stimulate discussions, and help students grasp the importance of microbes in shaping our environment and creating a sustainable future:

   - What are microbes? Can you name some examples of microbes that exist in our environment?
   - Why are microbes commonly considered germs?
   - How do bacteria manage to survive and thrive in places that seem inhospitable to other living organisms?
   - Why is it important to preserve and protect microbial diversity in natural environments?

4. **Exploring microbiological tools and techniques (10 min)**
   The teacher describes the laboratory instruments and technologies of a microbiologist. This part of the lesson aims at getting the students familiar with microscopy, molecular characterization techniques based on DNA sequencing, and bacteria cultivation. Example of engaging questions to students:
   - How can we study bacteria?
   - How is bacterial cultivation done in the laboratory, and why is it essential for microbiologists?

5. **Practical activity (10 min)**
   The teacher asks one volunteer class to "high five" classmates and leave its handprint on a 180 mm microbiological plate with LB or nutrient agar. Next, the plates are taken to the laboratory and should be incubated at 37° for a few days to let the colonies grow.

   After a few days the plates are brought back to the school to let the students compare the "class hand microbiomes".

6. **Experiment (30-40 min)**
   Pupils are introduced to the concept of "microcosm" and the Winogradsky Column experiment.
   Students should produce their Winogradsky column to be observed in the following three months.

   Implementation: The teacher asks volunteers to smash a boiled egg, cut out pieces of paper, mix mud and pond water (previously collected in the countryside) taking out vegetal residues. Then students mix mud, water, aquarium sand, egg and paper to set up the solid bottom of the Winogradsky column.
   Before adding the pond water to create the upper liquid part of the microcosm, students should be asked to choose how they would like to "pollute" their column, using either iron sulfate, ammonium nitrate (simulating contamination from agricultural fertilizers), sulfur, fragments of MaterBi from a biodegradable bag (simulating the environmental dispersion of bioplastics), or paraffin (simulating an "oil spill" on the water pond).
   Each class will obtain its column which will be placed on an illuminated table (close to the window) in the science laboratory of the school. If the school has a protected outside place tu store the column it would be better since they can become smelly after a while.

   Example of engaging questions:
   - What do you think will happen to the column over time as the bacteria grow and interact?
   - What role do bacteria play in Winogradsky's column, and how do they interact with the different layers?

7. **Bioremediation concept – introduction to the Nymphe project (20 min)**
   The teacher introduces the concept of Bioremediation and gives a simple explanation of what NYMPHE project is.

   Students are asked to recall the first part of the lesson in which bacteria living in polluted environments were given as examples and brought us to understand that bacteria not only can survive in such condition but can also perform removal or transformation of the pollutants by using the contaminants as a nutrient source.

Implementation: To explain the problem the teacher uses petroleum hydrocarbons as a simple example and introduces concepts such as carbon source for bacteria, environmental exposure, adaptation through DNA mutation and evolution rate of microbes.

The concepts of bioaugmentation and biostimulation are explained in a simple way. Students are also introduced to the advantages of bioremediation with respect to conventional incineration and removal techniques.

The NYMPHE concept can be presented by providing a parallel between the actual nature of environmental contamination, which is mixed, and the biodiversity of the microbial community, which provides an incredibly diverse metabolic potential. The basic idea that students should understand is that microbes work in teams with each other and with other (macro)organisms.

8. Feedback from teachers and students

Students and the science/biology teacher should be asked to provide feedback, general thoughts, ideas, and reflections.

Example of questions to students:

- What did you like about this experience?
- What sparked your interest in the topics we were discussing?

Science/biology teachers can be asked if the lesson and the level of presented information is suitable for the student's age and if there would be a possibility to incorporate in the teaching program more activities focused on microbiology and bioremediation and in what way.

As a continuation of the topics discussed during the lesson, the science/biology teacher can ask students to prepare essays on bioremediation as a part of civil education activities.

9. Experimental results

During the following days, plates on which bacteria from the hands of students that will be developed colonies of varied colours and shapes (after a couple of days of incubation at 37°C), will be given back to the school to be shown to students.

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