

# LOESS INTEGRATED LEARNING SCENARIO TEMPLATE

## Introduction

In [LOESS](#), the acquisition of soil health knowledge is facilitated using integrated STEM teaching and learning, which is carried out via the [Biology Science Curriculum Study \(BSCS\) 5E Instructional Model](#) by Bybee and colleagues (Bybee et al. 2006) as well as the application of innovative [pedagogical approaches](#) (PBL, IBL, etc).

## Keywords

**Biodiversity; fertility, biofertilization, rhizosphere, soil microbiome<sup>1</sup>, manage, sustainability.**

## Title

**Invisible Microbial Allies for Fertility and Health Soil**

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## Summary

The learning scenario highlights the soil as a physical space in which biogeochemical cycles take place, playing a vital role in the exchange of matter and energy within ecosystems. It highlights the crucial role of soil microorganisms, key players in these cycles, in soil fertilization. Practical investigation of microbial biodiversity and real-world applications will deepen the understanding of the importance of soil in ecosystems, agriculture and sustainability. The path will promote environmental awareness of also preserving the microbiological health of the soil, often undermined by pollutants released and the excessive use of fertilizers. Research and the use of digital resources and examples of agriculture 4.0, will be promoted to maximize learning outcomes.

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## Subjects

**Biology–Chemistry–Earth Science**

## Real-life questions

- How can we improve soil fertility in a sustainable way?
- What is the difference between fertilizers and biofertilizers?
- How can we reduce the use of fertilizers?

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<sup>1</sup> definition in [Annex I: Glossary](#)



- What traditional methods do we know?
- What innovative methods can we use?
- How biotechnology can help improve soil fertility

## Learning objectives

### Students will be able to:

- Explain how soil supports plant growth and the importance of soil in ecosystems;
- Conduct experiments to explore the rhizosphere microbiome
- Carry out a investigations about the soil bacteria (e.g. extraction of amylolytic bacteria from soil and prepare grow plates)
- Explain the ecological role of nitrogen-fixing bacteria and the symbiotic relationship they establish within the nodulated<sup>2</sup> roots of legumes
- Search for evidence (extract bacteria from nodule of plants and observe to m.o. - optical microscope)
- Introduce environmental sustainability starting from real-life situations, such as the consumption of legumes (broad beans and peas).
- Integrate concepts from Geology, Chemistry and Biology to gain a holistic understanding of soil health and its environmental impact;
- Design and set up experiences to answer a question
- Learn to identify "hidden" variables
- Use laboratory tools and techniques
- Reflect on the influence of environmental factors on living beings
- Reflect on biogeochemical cycles
- Learn to schematize

## Link to curriculum

This educational path considers the experiences and activities that are usually carried out on the soil in primary, secondary and higher schools and is alienated with the standards of numerous national curricula and sustainable development goals (SDG 2, SDG 12, SDG 15). The novelty is to recreate in STEM key, through IBSE and PBL approaches, many experiences that are usually conducted on the soil, developing scientific literacy and scientific citizenship. In this itinerary, starting from a few grams of soil and the root noduli of leguminous plants, the "reading of the environment" at the microscale (soil bacteria, microbiome soil) is proposed and privileged. To simplify the complexity of the ecological network of the soil microbiome, the pathway proposes amylolytic bacteria as an example of organic matter decomposing bacteria and nitrogen-fixing bacteria, such as **Rhizobium leguminosarum**, that convert atmospheric nitrogen into ammonia, making it available to plants. The process of nitrogen fixation, improves soil fertility and reduces the need for chemical fertilisers; in fact their use alters also the microbiome. This learning scenario promotes the IBSE approach according to the model of the **BSCS 5E** and develops students' skills in scientific research through **inquiry** ([Annex 2](#)), data analysis and critical thinking and it is easily replicable.

<sup>2</sup> definition in [Annex 1: Glossary](#)



## Age of students

14-18 years

## Time

**Preparation time: 2-3 hours**

**Teaching time:** approximately 5 lessons; 6/8 hours to carry out learning scenario

Subject 1: Biology

Subject 2: Chemistry

Subject 3: Earth Science

## Teaching resources (materials & online tools)

### Material for all lessons

- Computers/tablets.
- White board
- Paper
- Internet connection
- Printable materials

### Lesson 1

- Printable KWL table ([Annex 3](#))

### Lesson 2

- plastic shopping bags
- bioplastic shopping bag<sup>3</sup> (shopping bag made from starch: e.g. [Compostable Grocery Bags - Bharat Compostables](#))
- plastic pots or containers (transparent if possible)
- Lugol Iodine solution
- 5-10 ml pipettes/syringes
- plastic petri dishes or plates 10 cm
- soil samples
- scissors
- gloves
- labels and marker

### Lesson 3

- 10 plastic Petri dishes
- sterile water
- agar
- starch or frumin (you can buy it at the supermarket)
- soil sample
- 1 scale
- 2 graduated cylinders of 100 ml

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<sup>3</sup> definition in [Annex 1: Glossary](#).



- 1 funnel
- filter paper
- 500 ml conic flask or food jars
- 1 electric stove
- bain-marie pots
- Spatulas
- disposable gloves
- An oven mitt
- 5-10 ml pipettes/syringes
- sterile swabs/cotton swabs
- spoon/spatula spoon
- thermometer
- incubator/thermostat

#### **Lesson 4**

- Procure fava bean roots with nodules from farmers or family parents who have a vegetable garden
- -leguminous plants (fava bean plant with roots)
- fava bean roots with nodules for lesson 5

#### **Lesson 5**

- nodules of leguminous plants
- H<sub>2</sub>O<sub>2</sub> (3% hydrogen peroxide)
- denatured ethyl alcohol
- spray with water
- metal tweezers
- scissors
- scalpel
- paper
- watch slide
- microscope slides and coverslip
- methylene blue
- Bunsen burner
- microscope

#### **Online tools**

##### **Lesson 1**

- Video – "Caring for Soils: Measure, Monitor, Manage" (1 min)  
<https://www.fao.org/world-soil-day/en/> underscores the importance of accurate soil data and information in understanding soils characteristics and supporting informed decision-making on sustainable soil management for food security.
- <https://www.fao.org/soils-portal/en/> A source of soil information and knowledge on the different components and aspects of soils.
- Video – "Let's Talk About Soil" <https://youtu.be/invUp0SX49g> (5 min)



An animated film that describes the reality of soil resources around the world and explores the global challenges facing soil resources.

### Lesson 2

- Video - Keep soil alive, protect soil biodiversity [https://youtu.be/hbdsHOnd\\_gw](https://youtu.be/hbdsHOnd_gw)  
An educational animation by FAO that explains the importance of soil biodiversity and the threats that put it at risk.
- <https://www.fao.org/soils-portal/en/> A source of soil information and knowledge on the different components and aspects of soils.
- Video - Mission: Keep soil alive! FAO Ukraine's video animation for #WorldSoilDay <https://www.fao.org/global-soil-partnership/resources/highlights/detail/en/c/1361871/>
- Soil biodiversity (FAO) <https://www.fao.org/soils-portal/soil-biodiversity/en/>
- Global soil partnership (FAO) <https://www.fao.org/global-soil-partnership/areas-of-work/soil-fertility/en/>
- Video - What is Green Manure? How to apply to your garden or farm <https://www.youtube.com/watch?v=N9QP7IZ4lm8>
- Video - Soil biodiversity 101 <https://www.youtube.com/watch?v=iTlJeGgMTEF>

### Lesson 5

- Video - Understanding Our Soil: The Nitrogen Cycle, Fixers, and Fertilizer <https://www.youtube.com/watch?v=A8qTRBc8Bws>
- Video - The Nitrogen Cycle! <https://www.youtube.com/watch?v=uip4O6t7yfQ>

## STEM Strategy Criteria

Developing the LOESS learning scenario will help you and your school comply with the [STEM School Label criteria](#). Find below the criteria addressed by this learning scenario.

Elements and criteria	How is this criterion addressed in the learning scenario?
<b>Instruction</b>	
<b>Personalisation of learning</b>	The LS provides a series of hands-on activities that support the understanding of the fundamental concepts of Biology, Chemistry and Earth Sciences, the systemic study of science, and modelling. The BSCS 5E model teaching approach takes students through the salient phases of scientific research and develops 21st-century skills
<b>Problem and project-based learning (PBL)</b>	Pose some key questions, like: <i>"How can we sustainably improve soil fertility in this agricultural area while minimizing environmental impact?"</i> <i>How can we assess the soil fertility of our school's garden?</i>
<b>Inquiry-Based Science Education (IBSE)</b>	Doing Science through the process of investigation by applying the BSCs 5E (Engage, Explore, Explain, Elaborate, Evaluate) teaching model. However, the investigation will be applied through the selection of



Elements and criteria	How is this criterion addressed in the learning scenario?
	productive questions, to which students will be able to answer through a survey according to the indications provided by the teacher or designed by themselves. The questions must be investigable, scientifically connoted and related to the school curriculum.
<b>Curriculum implementation</b>	"The interdisciplinary approach guarantees that the curriculum is applied in accordance with national standards directly connected to curriculum objectives, including scientific literacy and environmental sustainability.
<b>Emphasis on STEM topics and competencies</b>	
<b>Interdisciplinary instruction</b>	The learning scenario allows interconnections between geography, biology, chemistry, geology, materials science, green biotechnology and to carry out practical activities that are easy to carry out.
<b>Contextualisation of STEM teaching</b>	In this Learning Scenario, students will be guided to search for alternative strategies to experimentally verify the microbiological fertility of soils and interact with companies operating in the field of bio sustainable fertilization.
<b>Assessment</b>	
<b>Continuous assessment</b>	The evaluations may include quizzes, case studies, personal journal labs, group reports, learning products, class participation, and informal observations.
<b>Personalized assessment</b>	Personalized assessment to individual students with special Educational Needs.
<b>Professionalization of staff</b>	
<b>Professional development</b>	The collaboration with the local university, the research center and the farms, will make it possible to enhance the scientific skills of the teachers involved on the soil topic and promote and improve the expertise in the application of innovative methodologies.
<b>School leadership and culture</b>	
<b>School leadership</b>	Encourages innovation, outdoor experiential learning and relationships with the partners that can be involved in LS.
<b>High level of cooperation among staff</b>	Activities may involve multiple staff members (e.g., teachers, assistant teachers, teachers of others departments).
<b>Inclusive culture</b>	The scenario is accessible to other teachers of the Department of Science and their students. The direct involvement of students from other classes can also be envisaged in the observations and management of the outdoor field. The presentation of the study on soil fertility and the experimental research tests can be carried out through a scientific seminar in <b>World Soil Day</b> (5 December) which includes a poster and images session.



Connections	
<b>With parents/guardians</b>	Farm parents are invited to contribute, providing soil samples with a known composition and legume seedlings to be transplanted into outdoor spaces; in spring parents, grandparents, uncles, can provide legume pies with root nodules.
<b>With other schools and/or educational platforms</b>	Collaboration and exchange of experience with primary and secondary school teachers interested in experiencing the learning scenario are planned.
<b>With universities and/or research centers</b>	The Department of Agricultural Sciences, Food, Natural Resources and Engineering-Foggia -Italy <a href="#">Homepage   Dipartimento di Scienze Agrarie, Alimenti, Risorse Naturali e Ingegneria</a> CREA, Council for Agricultural Research-Foggia -Italy <a href="#">CREA - Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria - CREA</a>
<b>With local communities</b>	Local agricultural nurseries and pharmacies
School infrastructure	
<b>Access to technology and equipment</b>	Access to informatic lab, use the digital board in the classroom and in Biology Lab. Access to BOYD as tablet and iPad for indoor and outdoor activities
<b>High quality instruction classroom materials</b>	It is guaranteed by : - equipped laboratory spaces and availability of materials, resources and rapid retrieval of equipment to carry out investigations; - adequate spaces for PBE and Inquiry activities; - trained and competent teachers.

### Description of activities

Name of activity	Procedure	Time
<b>1<sup>st</sup> Lesson</b>		
<b>5E Phase</b>	<b>Engage</b>	
<b>Brainstorming and discussion</b>	KWL chart printable Topic/Issue: SOIL FERTILITY ( <a href="#">Annex 3</a> ) graphic processing on whiteboard or digital whiteboard of group discussion and shared ideas	25'
<b>Discussion and preparation for the next lesson</b>	Video: World Soil Day <a href="https://www.fao.org/world-soil-day/en/">https://www.fao.org/world-soil-day/en/</a> "Caring for Soils: Measure, Monitor, Manage" Spotlight on World Soil Day	15'
<b>Outdoor activity</b>	The students, divided into groups, photograph cultivated and uncultivated green areas, collect soil samples and mark legume sowing areas.  Discussing about: When to sow fava beans There are two possible sowing periods for the fava bean (vicia faba) : you	20'



Name of activity	Procedure	Time
	<p>can choose to put the legume in the ground in autumn, so between October and November, or lean towards spring sowing, planting the seed between February and March. Winter sowing accelerates the development of the plant which as soon as the winter cold is over can develop at its best, in areas where it is very cold, however, it is better to wait until March arrives.</p>	
<b>2<sup>nd</sup> Lesson</b>		
<b>5E Phase</b>	<b>Engage, Explore, Evaluate</b>	
<b>Subject 1</b>	<b>Chemistry</b>	
<b>Plastic bags in the soil (Engage)</b>	<p>Real life situation: plastic bags in the soil Students examine a soil sample containing plastic bag fragments and discuss its transformation and the consequences of leaving it in the ground.</p>	10'
<b>Plastic or/and bioplastic bags in the soil (Explore)</b>	<p>The teacher gives each group two bags: one plastic bag and one bioplastic compostable bag (made from starch) Students read the information on each bag (composition, use, regulations) and write it down on the group sheet. <i>How can we verify that the bioplastic bag is made from starch?</i></p> <p>Students begin with ideas grounded in existing concepts and past experience and purpose the Lugol Iodine test.</p> <p>Students suggest using the Lugol test and prepare square-shaped (6cm x 6cm) samples of plastic and bioplastic bags; then place 2-3 drops of Lugol on each sample.</p> <p>The teacher inquires: "What are the expected results?" The students share the idea that the Lugol Iodine will turn dark (black) on the bioplastic bag while its color will remain unchanged on the plastic bag.</p> <p>Extension activities: detection of amylolytic enzymes in saliva (<a href="#">Annex 11</a>, alternative experiment in <a href="#">Annex 12</a>)</p>	15'
<b>Plastic or/and bioplastic bags in the soil (Explore and Explain)</b>	<p>The teacher helps students identify scientific issues, determine keywords (see glossary <a href="#">Annex 1</a>) for searching scientific information, and recognize key characteristics of scientific research.</p> <p>Students conduct web research on the difference between soil degradability and soil biodegradability. <i>«Degradability and biodegradability in soil refer to a substance's ability to break down through natural, chemical and/or biological processes. Factors such as temperature, humidity, and microbial activity significantly influence the degradation of plastics and bioplastic. However, bioplastics (e. g., a shopping bag made from starch) tend to degrade more rapidly in controlled composting environments compared to soil or water. This research underscores the importance of proper disposal and recycling to mitigate environmental impact and protect soil quality».</i></p>	20'
<b>Subject 2</b>	<b>Earth Science–Geology</b>	



Name of activity	Procedure	Time
<p><b>Plastic and bioplastic bags in the soil (Explore)</b></p>	<p>Plastic and bioplastic bags in the soil «How can we compare the biodegradability of starch bags in soil with the degradability of a plastic bag in the same soil?»</p> <p>The teacher forms groups of 4-5 students and provides each group with one plastic bag and one bioplastic bag. New experience or problem Investigable questions identified:</p> <p><i>«Design an investigation to determine if biodegradable plastic bags degrade faster than conventional plastic bags in soil»</i></p> <p>Each group's experimental design is shared on the digital board. The best procedure is selected:</p> <ul style="list-style-type: none"> <li>- fill medium-sized plastic pots (transparent if possible) with soil;</li> <li>- place both samples of plastic bag and bioplastic bag in own pots or in a single pot but at distance;</li> <li>- insert a stick with the label in correspondence with each sample.</li> </ul> <p>The plastic and bioplastic samples are placed in the soil of each pot and their location is marked with labels. The variables identified include temperature, humidity and exposure to sunlight.</p> <p>The teacher invites the students to request the necessary materials which are displayed on the desk and provides students with a sample lab journals (<a href="#">Annex 4</a>: format editable and printable) that they will have to fill individually and in group.</p> <p>The teacher guides the students through the inquiry process.</p> <p>Students will annotate the investigable question, initial hypothesis, predictions, data collection, comparison of results with predictions, and evidence related to the original idea.</p> <p>Students record the results in the table Investigation n.2 - Plastic and bioplastic bags in the soil (<a href="#">Annex 5</a>).</p> <p>Note; <i>The teacher can show students the result of previous investigations while waiting for the time necessary for the degradation of the bags in the pots (a couple of months).</i> The teacher can show photos, videos or material of the laboratory tests carried out previously</p>	<p>20'</p>





Name of activity	Procedure	Time
	 <p>Students, through the inquiry must be able to: develop predictions, descriptions, explanations and model using evidence; think critically and logically to establish relationships between evidence and explanations ; recognize and analyse alternative explanations and predictions. communicate scientific procedure and explanations.</p>	
<p><b>Plastic and bioplastic bags in the soil (Explain)</b></p>	<p>During and at the end of their exploration, students will explain the results of their soil investigations.</p>	<p>20'</p>
<p><b>Plastic and bioplastic bags in the soil (Elaborate)</b></p>	<p>During the "elaborate step", students can: connect ideas, solve problems, and apply their understanding to new situations; use scientific terms and descriptions; draw reasonable conclusions from evidence and data, such as the presence of decomposer microorganisms <u>like amylolytic bacteria</u>; deepen their understanding of concepts and processes; communicate their understanding to others. They may identify potential threats to soil health and formulate possible solutions to enhance soil fertility.</p>	<p>20'</p>
<p><b>Plastic and bioplastic bags in the soil (Evaluate)</b></p>	<p>Students enhance their comprehension of scientific inquiry by conducting their own investigations and critically assessing those carried out by their peers. At the end of this investigation, students: will present the final results ; will show that the bioplastic bag deteriorates and flakes to the touch because they are degraded by microorganism (amylolytique bacteria?) while the plastic bags remain intact. Conclusion : Soil bacteria and microorganisms are essential for biodegradation, regenerating matter in biogeochemical cycles, and maintaining soil fertility. In this experience we tested the action of starch-degrading bacteria. In addition, for example, in the soil there are bacteria (eg cellulolytic bacteria) that degrade the cellulose as we can deduce from</p>	<p>20'</p>



Name of activity	Procedure	Time
	degradation of the foliar page of some leaves that we found in the soil in outdoor spaces.	
<b>Learning products</b>	<a href="#">Annex 4</a> - Lab journal activities <a href="#">Annex 5</a> - Table Investigation n.2 Plastic and bioplastic bags in the soil Documentation of laboratory activities through photographs and videos.	
<b>3<sup>rd</sup> Lesson</b>		
<b>5E Phase</b>	<b>Explore, Explain</b>	
<b>Subject 3</b>	<b>Biology</b>	
<b>Soil Amylolytic Bacteria in vitro (Explore)</b>	<p>The teacher forms groups of 4-5 students</p> <p>New Investigable questions:  <i>How can we highlight the presence of soil amylolytic bacteria?</i>  <i>How can we study their ability to degrade starch?</i></p> <p>Task : draw an investigation to extract bacteria from the soil and isolate amylolytic bacteria.</p> <p>Each group's experimental design is shared on the digital board. The best procedure is selected.</p> <p><i>Note : in this case the procedure can be indicated by the teacher (structured inquiry) or designed by the students if they have a good background of bacterial cultures in the plate (guided inquiry).</i></p> <p><u>Extraction of bacteria from the soil</u>            Procedure</p> <ul style="list-style-type: none"> <li>• Weigh 30 g of soil</li> <li>• Mix the soil sample with 90 ml of sterile water (5g of soil/15 ml of sterile water; <i>sterilize water by boiling</i>)</li> <li>• Pour the water/soil mixture into the funnel with filter paper</li> <li>• Filter</li> </ul> <p><u>Materials needed for the preparation of 10 plates</u>            (the plates can be prepared beforehand)</p> <ul style="list-style-type: none"> <li>• 10 plates (20 ml of medium for each plate)</li> <li>• -200 ml of stérile water</li> <li>• -4g of agar / 200ml of sterile water (20g of agar / litre)</li> <li>• 1 g of frumina (you can buy it at the supermarket)</li> <li>• A soil sample (see extraction)</li> <li>• 1 scale</li> <li>• 2 graduated cylinders of 100 ml</li> <li>• 1 funnel</li> <li>• Filter paper</li> <li>• 500 ml conical flask or food jars</li> <li>• 1 electric stove</li> <li>• Bain-marie pots</li> <li>• Lugs/spatulas</li> <li>• Disposable gloves</li> <li>• An oven mitt</li> <li>• 5-10 ml pipettes/syringes</li> <li>• Sterile swabs/cotton swabs</li> <li>• spoon/spatula spoon</li> <li>• thermometer</li> <li>• incubator/thermostat</li> </ul> <p><u>How to prepare a culture</u></p>	60'

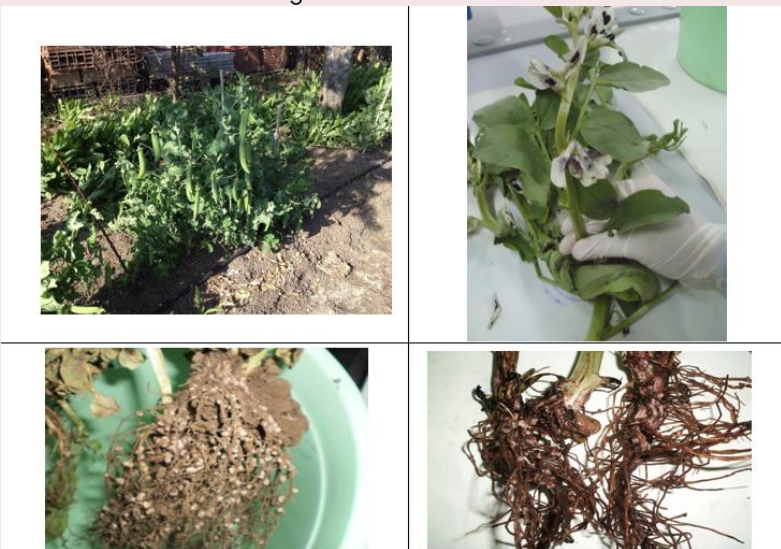


Name of activity	Procedure	Time
	<ul style="list-style-type: none"> <li>To prepare a culture medium, it would be necessary to operate in sterile conditions (under a sterile hood) and have an autoclave available.</li> <li>At school you can work by trying to get as close as possible to operational situations in which contamination is minimal.</li> <li>Laboratory glassware can be replaced by commonly used material that adapts to the realization of the activity. The culture medium can also be prepared during a previous lesson, as long as it is properly sterilized and stored in the refrigerator at 4°C.</li> <li>You can use the flame of a Bunsen burner to make the environment near the plates you are working on sterile.</li> <li>Note: Prepare control plates to be inoculated with sterile water only.</li> </ul> <p><u>Techniques for seeding bacteria in the plate</u> You can discuss with the students the different techniques that can be used for plate seeding and which is the most suitable to use among those listed below:</p> <ul style="list-style-type: none"> <li>sowing by smear;</li> <li>seeding by inclusion;</li> <li>sowing by spatula.</li> </ul> <p>Before sowing, the plates must be marked with a label Incubation of the plates Incubate the plates in the thermostat for 48 hours at 37°C (temperature standard for bacterial growth). The orientation of plates is crucial; they should be incubated inverted (lid facing downwards) to avoid condensation from dripping onto the culture medium.</p>	
<p><b>Soil Amylolytic Bacteria in vitro (Explain)</b></p>	<p>After 48 hours, the teacher gives each group of students their plates. They proceed to observe, photograph the microbial growth, interpret the results and perform the Lugol test. Teacher gives some information on how to interpret the microbial growth. The growth medium made of agar and starch favored the growth of white colonies (amylolytic bacteria?). <i>How can we verify that white colonies are amylolytic bacteria?</i> Each group applies Lugol's iodine to its samples (1-2 drops around the colonies) Results : the culture medium will appear black due to the presence of starch, except in the area where the starch has been digested by bacteria.</p>   <p>Explain the results: each group writes a concise explanatory text: observations from the Lugol test (e.g., what the color change indicates).</p>	20'



Name of activity	Procedure	Time
	whether the results support the initial hypothesis and predictions. how their findings align or differ from the predicted outcomes. Groups take clear and detailed photographs of the outcomes, capturing any significant changes or observations to accompany their analysis.	
<b>Learning products</b>	Lab Journal ( <a href="#">Annex 4</a> ) Documentation of laboratory activities through photographs and videos	
<b>4<sup>th</sup> Lesson</b>		
<b>5E Phase</b>	<b>Engage, Explore, Explain, Elaborate</b>	
<b>Subject 3</b>	<b>Biology</b>	
<b>Introduction to bio-fertilisers</b>	Video –Keep soil alive, protect soil biodiversity <a href="#">Keep soil alive, protect soil biodiversity</a> <a href="https://www.fao.org/soils-portal/en/En_IYS_food_Print.pdf">https://www.fao.org/soils-portal/en/En_IYS_food_Print.pdf</a> The lesson starts with a video on soil microbial biodiversity and its role in ecosystem balance Then, the teacher forms groups and provides an abstract of the scientific article “Biofertilizers: a sustainable solution for enhancing soil fertility and crop productivity” for reading <i>“Abstract- In current agricultural practices, chemical fertilizers have reduced soil fertility, descriptions unsuitable for the cultivation of cultivated plants. In addition, excessive use of these inputs has also contributed to serious health and environmental risks such as soil erosion, water pollution, pesticide poisoning, low water levels underground, recording water, and depleting biodiversity. Biofertilizers automatically activate microorganisms present in the soil in an efficient and environmentally friendly way, gaining greater importance for use in agricultural production, restoring soil fertility and protecting it from drought and soil diseases and thus stimulating plant growth. Many scientists agree that the appropriate use of biofertilizers to enrich the soil is suitable for long-term sustainability. Moreover, it does not pose any danger to the environment and can be replaced with chemical fertilizers. The use of biofertilizers can reduce the use of chemical fertilizers, reduce environmental hazards, enhance soil structure, and promote agriculture.</i> <a href="#">Biofertilizers: a sustainable solution for enhancing soil fertility and crop productivity - ScienceDirect</a> Students in their group discuss the text’s meaning and the difference between biofertilizers and ancient green manure techniques. Further reading- <a href="#">Role of Plant Growth Promoting Rhizobacteria in Agricultural Sustainability—A Review - PMC</a> To learn more Key word: biofertilizers Questions: <i>What are PGPR (Plant Growth Promoting Rhizobacteria)?</i> <i>How do PGPRs work?</i> <i>Why are they important?</i> To learn more for teachers : <a href="#">Lesson 3.3 - Plant Growth Promoting Rhizobacteria (PGPR) :</a> <a href="https://youtu.be/RKE9a2p8ZX4">https://youtu.be/RKE9a2p8ZX4</a>	20’



Name of activity	Procedure	Time
<p><b>Let's biofertilize the soil – Outdoor activity</b></p>	<p>If fava beans have been planted: monitor the growth of fava beans, peas and clover. Harvest plants with root nodules and discuss green manure techniques, nitrogen cycling, and nitrogen-fixing bacteria based on students' scientific backgrounds.</p> 	<p>20 '</p>
<p><b>Let's biofertilize the soil – Indoor activity</b></p>	<p>Teacher show the videos : Understanding Our Soil : the Nitrogen Cycle, Fixer and Fertilizer</p> <p><a href="#">The Nitrogen Cycle!</a> (additional information in <a href="#">Annex 13</a>)</p> <p>Students work in group and create a brief summary on the importance of green manure and how nitrogen-fixing bacteria convert inorganic nitrogen into organic compounds.</p> <p>They schematize the nitrogen cycle and write on your copybook about the chemical reactions of nitrogen fixation; after of this they do web searches on the role of the nitrogenase enzyme (<a href="#">see glossary annex 1</a>). Nitrogenase is a crucial enzyme in the nitrogen cycle, responsible for the biological fixation of this element. In particular, it catalyzes the conversion of atmospheric nitrogen (N<sub>2</sub>) into ammonia (NH<sub>3</sub>), a form that can be used by plants and other organisms. This process occurs mainly in nitrogen-fixing bacteria, such as those belonging to the genera Rhizobium (which live in symbiosis with the roots of legumes) and Azotobacter (bacteria free in the soil).</p> <p>The groups discuss, formulate, and share the following conclusion:  <i>"Farmers have long recognized the benefits of this technique on soil. Today, green manure is essential for reducing harmful chemicals in fertilisation, promoting sustainability, conserving resources, and meeting food demand. Scientists twidly support their use as a long term sustaninable alternative to chemical fertilize.</i></p>	
<p><b>Learning products</b></p>	<p>Outdoor and indoor activities photos</p>	





Name of activity	Procedure	Time
	<p>Students share microscope photos of their slides on the If the experiment has been performed correctly, students can conclude that bacteria that science classifies as nitrogen-fixing bacteria are present in the root nodules.</p>	20'
	<p><b>ELABORATE</b> During the elaboration, students can : connect ideas, solve problems, and apply their understanding to new situations ; use scientific terms and descriptions ; draw reasonable conclusions from evidence and data, such as nitrogen-fixing bacteria (bacterioids) at m.o. ; deepen their understanding of concepts and processes; communicate their understanding to others. The students highlight the ecological role of nitrogen-fixing bacteria, which they play through symbiosis with the roots of certain plants, and emphasise their importance for soil fertilisation. They may identify potential threats to soil health and formulate possible solutions to enhance soil fertility.</p>	20'
	<p><b>EVALUATE</b> Students enhance their comprehension of scientific inquiry by conducting their own investigations and critically assessing those carried out by their peers. At the end of this investigation, students: will present their conclusions and final results ;</p> <p>During the elaboration phase and at the end of this investigation students will share their conclusions, each group will self-evaluate its work and evaluate the work of the other groups. Better end results will be shared. Conclusion : Soil bacteria and microorganisms are essential for biodegradation, regenerating matter in biogeochemical cycles, and maintaining soil fertility. For this reason, the microbiome must be preserved from the excessive use of fertilizers. A valid alternative for soil sustainability to green manure techniques could be the use of biofertilizers.</p>	20'
<p><b>Learning products</b></p>	<p>Documentation of laboratory activities through photographs and videos ; microscope photos.</p>	



## Initial assessment

- [Table KWL](#)– The first two columns, K and L, of the KWL table can be used to animate brainstorming, to bring out scientific knowledge about soil, any misconceptions and what each student wants to know. (Es Topic: soil; Topic: who lives in the soil?)
- Class Discussions: guided discussions allow teacher to gauge comprehension and clarify misconceptions.

## Formative evaluation

- class discussions to share the phases of inquiry (evaluation rubric in [Annex 6](#))
- conceptual understanding tests (see [Annex 7](#), [Annex 8](#)):
- short quizzes and activities ([Annex 9](#), [Annex 10](#))
- written reflections that can assess whether students grasp the scientific principles behind the inquiry.
- lab Journal: structured formats help students document their observations, methods, and conclusions systematically.

## Final assessment

- Short standardized questionnaire ([Annex 14](#), [Annex 15](#))
- Lab Activity Journal
- Solving a case study or case of real life ([Annex 16](#))
- Oral presentation

## Student feedback

- Oral discussion and presentation on the investigations carried out
- During the elaboration phase and at the end of investigations, students will share their conclusions, each group will self-evaluate its work and evaluate the work of the other groups. Better end results will be shared.

## Teacher feedback

*Teachers share the rubric scientific inquiry evaluation rubric and discuss the level achieved individually and in a group (Annex 5)*



## Reflection on the development process

My initial idea for my learning scenario (LS) stems from the need to focus on the microbial biodiversity of the soil and the role it plays in every ecosystems. In my paths, under the guidance of teachers, students can engage in diverse theoretical and experimental investigations tailored to the teaching context, the availability of tools, and materials. Using simple resources like soil, nodulated roots from clover and broad beans, legume seeds, and minimal equipment, students can cultivate plants, extract and observe soil bacteria (amylolitic bacteria) and analyze their impact on eukaryotic organisms and the environment. Beginning with the observation of a seed's transformation under basic growth conditions, students can progress to designing laboratory activities that focus on variables and their effects over time. This exploration can culminate in developing an experimental system to study symbiotic relationships and their implications.

I delved into various resources, including scientific articles on soil. These resources provided valuable insights into integrating interdisciplinary approaches, combining biology, chemistry, geology, biotechnology, geography, while also ensuring the content remains accessible and engaging. They shaped my decision to emphasize both the practical and theoretical aspects of soil study, brought I'IBSE and applying the 5E model. I learned that a good planning process takes time and attention. It is important to be flexible but also to have a clear vision of the goals to be achieved.

So the proposed learning scenario model and the entire course have been of great help to me to better manage my work, keep my motivation high to update myself, experiment also through peer comparison.



## Annex 1: Glossary

Term	Definition
<b>Amylase</b>	An enzyme that catalyzes the hydrolysis of starch into sugars. Found in saliva, pancreas, and microbes.
<b>Amyolytic Bacteria</b>	Microorganisms capable of producing amylase enzymes to break down starch into simpler sugars. Often used in fermentation and soil nutrient cycling.
<b>Bacteria</b>	Single-celled prokaryotic organisms that exist in diverse environments. They play roles in decomposition, fermentation, and disease, as well as beneficial functions like nitrogen fixation.
<b>Biodegradable</b>	Material to break down by microorganisms, but not necessarily under composting conditions
<b>Biodiversity</b>	The variety of life forms within an ecosystem, including plants, animals, fungi, and microorganisms.
<b>Biofertilization</b>	The enhancement of soil fertility through beneficial microorganisms that increase nutrient availability for plants.
<b>Biofertilizer</b>	A substance containing living microorganisms that enhance plant growth by increasing nutrient availability, especially nitrogen and phosphorus. Examples include Rhizobium, Azospirillum, and mycorrhizae.
<b>Compostable</b>	Capable of decomposing into natural elements in a compost environment, typically within a few months
<b>Cover Crops</b>	Plants grown primarily to improve soil health, prevent erosion, and enhance biodiversity. Common examples include clover, rye, and vetch.
<b>Enzyme</b>	Biological catalysts made of proteins that speed up chemical reactions in living organisms without being consumed.
<b>Biofertilization</b>	The enhancement of soil fertility through beneficial microorganisms that increase nutrient availability for plants.
<b>Fertility</b>	The ability of soil to support plant growth by providing essential nutrients, water, and suitable conditions.
<b>Fertimeter</b>	A device used to measure the nutrient content (especially nitrogen, phosphorus, potassium) in soil or plant sap to guide fertilization.



<b>Glossary Loess Project</b>	<u>Glossary: list of terms - Loess Project</u>
<b>Green Manure</b>	Crops grown and then incorporated into the soil to improve fertility and organic matter. Legumes are commonly used due to their nitrogen-fixing ability.
<b>Manage</b>	To apply strategies or practices to control, maintain, or improve a biological or ecological system.
<b>Microbiome</b>	The community of microorganisms living in a specific environment, such as for example the human body or soil.
<b>PGPR (Plant Growth- Promoting Rhizobacteria)</b>	Beneficial bacteria that colonize plant roots and stimulate growth by producing hormones, enhancing nutrient uptake, or protecting against pathogens.
<b>Nitrogenase</b>	An enzyme complex found in nitrogen-fixing bacteria that converts atmospheric nitrogen (N <sub>2</sub> ) into ammonia (NH <sub>3</sub> ), a form usable by plants.
<b>Nitrogen-Fixing Bacteria</b>	Microbes that convert atmospheric nitrogen into forms usable by plants. Examples include Rhizobium (in legumes) and Azotobacter (free-living).
<b>Rhizobium leguminosarum</b>	A nitrogen-fixing bacterium that forms symbiotic relationships with legume roots, improving soil fertility.
<b>Rhizosphere</b>	The soil region directly influenced by root secretions and microbial activity, crucial for plant-microbe interactions.
<b>Starch-based bioplastic:</b>	A type of bioplastic made from natural starch (e.g., corn, potato, tapioca). It's often used to produce compostable bags and packaging.
<b>Soil Microbiome</b>	The collection of microorganisms in the soil that affect nutrient cycling, plant health, and soil structure.
<b>Sustainability</b>	Using resources in a way that meets current needs without compromising future generations' ability to meet theirs.



## Annex 2: Science as inquiry

### Science as Inquiry

The teacher asks a question that can be answered through scientific investigations; students are invited to think and formulate hypotheses and predictions before individually, after compare them in their group to arrive at a shared idea.

Students, through the inquiry, must be able to:

- identify questions that can be answered through scientific investigations;
- develop descriptions, explanations, predictions and models using evidence;
- think critically and logically to establish relationships between evidence and explanations;
- recognize and analyse alternative explanations and predictions;
- communicate scientific procedures and explanations.

LESSON	Scientific question- Investigable question for every lesson
1 <sup>st</sup> Lesson	ENGAGE KWL table - Topic/Issue: SOIL FERTILITY
2 <sup>nd</sup> Lesson	« <i>How can we verify that the bioplastic bag is made from starch?</i> »
2 <sup>nd</sup> Lesson	Plastic and bioplastic bags in the soil <i>How can we compare the biodegradability of starch bags in soil with the degradability of a plastic bag in the same soil?</i>
3 <sup>rd</sup> Lesson	Plastic and bioplastic bags in the soil <i>How can we highlight the presence of soil amylolytic bacteria? How can we study their ability to degrade starch?</i>
4 <sup>th</sup> Lesson	ENGAGE THE SOIL FOOD WEB <a href="#">Keep soil alive, protect soil biodiversity</a> Reading activities: scientific article "Biofertilizers: a sustainable solution for enhancing soil fertility and crop productivity" <a href="#">Biofertilizers: a sustainable solution for enhancing soil fertility and crop productivity - ScienceDirect</a> Students in their group discuss the text's meaning and the difference between biofertilizers and ancient green manure techniques.
5 <sup>th</sup> Lesson	Let's biofertilizer the soil « <i>How can we confirm nitrogen-fixing bacteria are inside the nodules of roots ?</i> »
TECHNOLOGY	To learn more for teachers :



<p>Lesson 2-3-4-5</p>	<p><a href="#">Lesson 3.3 – Plant Growth Promoting Rhizobacteria (PGPR)</a></p> <p>Plant growth-promoting rhizobacteria (PGPR) are <b>specialized bacterial communities inhabiting the root rhizosphere</b> and the secretion of root exudates helps to, regulate the microbial dynamics and their interactions with the plants.</p> <p><a href="#">Fertimetro, a Principle and Device to Measure Soil Nutrient Availability for Plants by Microbial Degradation Rates on Differently-Spiked Buried Threads</a> <a href="#">Il Fertimetro ha vinto il Premio Innovazione Fieragricola 2016     Università di Padova</a></p> <p>The Fertimeter is a device that is inserted into the soil and estimates its fertility according to the progressive degradation of cotton and silk threads due to the action of the microorganisms present. 8 threads are used, 2 in silk and 2 in untreated cotton, another 4 similar, but impregnated with nitrogen and potassium phosphate. The relationship between the different thread break times provides a series of information on the type of microorganisms present, on the mineralization times of the organic matter and therefore on any nutrient deficiencies. The Fertimetro, combined with soil temperature and moisture sensors, is compatible with all iMetos 3.3 devices (weather stations and other dataloggers) that communicate with the FieldClimate web platform and can be consulted from smartphones with the appropriate applications.</p> <p>Innovation. The concept was developed by the University of Padova which, modified and adapted to be implemented in the iMetos system, becomes one of the IoT applications integrated into the holistic offer for smart agriculture. Knowing the nutritional status of the soil in the field and at low cost contributes to the optimization of fertilization or to the evaluation of the quality and potential of uncultivated land.</p> <p><a href="#">(Squartini Fieragricola 2016 [modalità compatibilità])</a></p>
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**Annex 3: KWL table for Lesson 1**

Add here your personal reflection on the creation of your learning scenario (max 200 words).

Name: \_\_\_\_\_ Date: \_\_\_\_\_

KWL Chart Select a topic you want to research. In the first column, write what you already know about the topic. In the second column, write what you want to know about the topic. After you have completed your research, write what you learned in the third column.

TOPIC: SOIL FERTILITY		
I Know	What I Want to Know	What I Learned



**Annex 4: Lab journal template**

**FORMAT SOIL INVESTIGATION LAB JOURNAL**

**Date** \_\_\_\_\_

**Student** (name and surname) \_\_\_\_\_

**Work group members** (name and surname) \_\_\_\_\_;

\_\_\_\_\_;

\_\_\_\_\_;

**1. Scientific question**

Eg .investigable question 2<sup>nd</sup> lesson

***How can we verify that the bioplastic shopping bag is made from starch? "***

**2. Hypothesis:** what is your educated guess to question? Explain your reason

**3. Prediction:** what is your prediction? What happens if ....?

**4. Modified Hypothesis:** after setting up your investigation, has your educated guess changed? If so, write your modified hypothesis and explain your reasoning

**5. Materials;** what materials will you use to investigate?

**6. Procedure:**

**7. Data collection:** record and display your data in a chart, table, picture or graph

**8. Results:** summarize the most important observations and changes that occurred during investigation

**9. Conclusions:** summarize the main points of the investigation.

*Were your hypothesis and prediction correct or not?*

*Why do you think your hypothesis and prediction were or were not correct? How could the investigation be improved if it were run again?*



**Annex 5: Lesson 2 worksheet – biodegradable bags**

2 <sup>nd</sup> Lesson					
<b>Table Investigation n.2 – Plastic and bioplastic bags in the soil</b>					
Record observations and results in the table. Compare results obtained with expected results (initial predictions)		<b>Biodegradable starch-based bag</b>  <b>Initial predictions:</b> the bag will undergo progressive deterioration		<b>Non-biodegradable bag</b>  <b>Initial predictions:</b> the bag will not undergo progressive deterioration	
Week	Date	Observations	Results discussion	Observations	Results discussion
Start of investigation					
first week					
second week					
third week					



## Annex 6: Scientific inquiry evaluation rubric

### SCIENTIFIC INQUIRY EVALUATION RUBRIC

LEVELS: Basic- Intermediate - Advanced

LEVEL	Excellent Advanced	Good Intermediate	Sufficient Basic Needs to be improved	Insufficient Needs to be improved
<b>Hypothesis</b>	Clearly stated Complete sentence Explanation is detailed, logical and strongly supports prediction.	Clearly stated Reasonable prediction. Satisfactory explanation supports prediction.	Reasonable prediction. Explanation do not show strong logic o reasoning to support the prediction	Lacks clarity. Hypothesis do not relate to the scientific question. No explanation is given to support the prediction.
<b>Materials</b>	All necessary materials are listed All materials are accurately described	All materials needed are listed. Some are not accurately described.	The list of materials is missing some items.	The list of materials is not given
<b>Procedure</b>	A plan is detailed and clear. All steps are included in order. Steps are detailed, complete sentences.	A plan is needs some clarification. Some steps are missing. Some steps need more detail	A plan is satisfactory but needs clarification. Some steps are missing or are out of order. Some steps need more detail. Not all steps are in complete sentences.	A plan need a lot of clarification. Important steps are missing and are out of order Most steps need more detail. Steps are note written in sentences.
<b>Data collection</b>	Recorded observations are accurate and detailed. Charts, tables, diagrams or graphs are accurate, complete detailed titled and labelled.	Recorded observations are accurate but could have more detail. Chart, table, diagram or graph is accurate but lacks some details.	Some recorded observations are inaccurate, lack detail. Charts, tables, diagrams or graphs are incomplete, inaccurate, incorrectly labeled	Recorded observations are inaccurate, lack detail. No charts, tables, diagrams or graphs
<b>Results</b>	Results are expressed clearly, accurately and in detail. Some patterns are described well in a written summary statement	Data results are expressed accurately, but some further explanation is needed. Some patterns are described well in a general summary statement. Sentence structure needs to be clearer.	Data results are expressed in a summary way. Results are provided in incomplete sentences.	Data results are expressed inaccurately. Results are given in incomplete sentences
<b>Conclusions</b>	Clearly explained Complete sentences Explanation s detailed, logical and strongly supports differences from prediction.	Clearly explained Reasonable explanation supports conclusions and differences from prediction	Explanation lacks detail or good logic Some sentences are incomplete and don't support conclusions and differences from prediction	Conclusion lacks clarity Conclusion doesn't fit with the result and data. No explanation to support the conclusions. Sentences are incomplete.



## Annex 7: Formative evaluation, quiz 1 – Bacteria and Amylolytic bacteria

### Science Quizzes: Bacteria and Amylolytic Bacteria

#### Science Quiz 1

**School Name:** \_\_\_\_\_

**Date:** \_\_\_\_\_

**Student Name:** \_\_\_\_\_

#### Instructions:

Circle the correct answer for each question. Each question has only one correct option.

#### General Questions on Bacteria

##### 1. What are bacteria?

- a) Multicellular fungi
- b) Single-celled microorganisms
- c) Insects
- d) Viruses

##### 2. Which of the following is a beneficial role of bacteria?

- a) Causing diseases
- b) Producing oxygen
- c) Decomposing organic matter
- d) Blocking sunlight

##### 3. Where can bacteria be found?

- a) Only in dirty places
- b) Only in water
- c) Only inside the human body
- d) Everywhere

##### 4. What shape can bacteria have?

- a) Only round
- b) Only spiral
- c) Only rod-shaped
- d) Round, spiral, or rod-shaped

##### 5. How do bacteria reproduce?

- a) Sexual reproduction
- b) Binary fission
- c) Budding



d) Spore formation

**Answer Key (for teacher use):**

B Explanation: Bacteria are unicellular organisms without a nucleus, classified as prokaryotes.

C Explanation: Many bacteria help break down organic waste, recycling nutrients in ecosystems.

D Explanation: Bacteria are found in soil, water, air, on surfaces and inside living organisms—even in extreme environments.

D Explanation: Bacteria come in various shapes: cocci (round), bacilli (rod-shaped), and spirilla (spiral).

B Explanation: Most bacteria reproduce asexually through binary fission, where one cell splits into two identical cells.



## Annex 8: Formative evaluation, quiz 1 – Decomposer Bacteria and Sustainability

### Science Quiz 2 : Decomposer Bacteria and Sustainability

**School Name:** \_\_\_\_\_

**Date:** \_\_\_\_\_

**Student Name:** \_\_\_\_\_

#### Instructions:

Circle the correct answer for each question. Only one answer is correct per question.

#### Part A: Understanding Bacteria and Decomposers

##### What is the role of decomposer bacteria in nature?

- a) They produce oxygen
- b) They break down organic matter
- c) They cause diseases
- d) They absorb sunlight

##### Which of the following is an example of a decomposer?

- a) Earthworm
- b) Amylolytic bacteria
- c) Oak tree
- d) Butterfly

##### Amylolytic bacteria produce which enzyme?

- a) Lipase
- b) Protease
- c) Amylase
- d) Cellulase

##### What does the enzyme amylase break down?

- a) Proteins
- b) Fats
- c) Starch
- d) Plastic

#### Part B: Real-Life Applications and Sustainability

##### Why are starch-based bags considered more environmentally friendly than plastic bags?

- a) They are cheaper to produce
- b) They are stronger
- c) They biodegrade faster
- d) They are waterproof



**What happens to starch-based bags when decomposer bacteria act on them?**

- a) They melt
- b) They become toxic
- c) They break down into natural substances
- d) They turn into plastic

**Which of the following materials is NOT biodegradable?**

- a) Banana peel
- b) Paper
- c) Plastic bag
- d) Cotton cloth

**How can students contribute to environmental sustainability?**

- a) Use more plastic bags
- b) Avoid recycling
- c) Choose biodegradable products
- d) Burn waste

**Answer Key (for teacher use):**

- b
- b
- c
- c
- c
- c
- c
- c





## Annex 9: Activities

### Identify biodegradable materials

Mark with YES all the materials in the table that are biodegradable and with NO the materials that are not biodegradable.

Comparative Table: Biodegradability of Materials

Material	Biodegradable?	Time to decompose	Decomposed by
Plastic shopping bag			
Starch-based bag			
Banana peel			
Paper			
Aluminum foil			

Comparative Table: Biodegradability of Materials (answer key)

Material	Biodegradable?	Time to decompose	Decomposed by
Plastic shopping bag	✗ No	100–500 years	Not easily decomposed
Starch-based bag	☑ Yes	Weeks to months	Bacteria, fungi, enzymes
Banana peel	☑ Yes	A few weeks	Decomposer bacteria, insects
Paper	☑ Yes	2–5 months	Moisture, microbes
Aluminum foil	✗ No	Hundreds of years	Not biodegradable

### Compare decomposition times

Which material decomposes the fastest?

Which one takes the longest?



### **Match decomposers**

For each biodegradable material, write down what helps it decompose.

### **Critical thinking**

Why is it important to use biodegradable materials in everyday life?

### **Creative challenge**

Imagine you're designing a new eco-friendly product.

What material would you choose and why?

Teaching recommendation: organize a laboratory session for the synthesis of bioplastic derived from starch, followed by an experiment to assess its biodegradability in soil. It is suggested to conduct the experiments according to the IBSE approach ([see Annex 3 - Science as Inquiry](#)) and the 5E model (engage, explore, explain, elaborate, evaluation).



## Annex 10: Reading activity

### Science Worksheet: Amylolytic Bacteria and their Ecological Role

**School Name:** \_\_\_\_\_

**Date:** \_\_\_\_\_

**Student Name:** \_\_\_\_\_

Reading Passage: Amylolytic Bacteria: Nature's Starch Decomposers

Amylolytic bacteria are a type of microorganism that produces an enzyme called amylase. This enzyme breaks down starch, a complex carbohydrate present in many plants. These bacteria are commonly found in soil, compost, and decomposing organic matter. Starch is a polymer of glucose. Amylolytic bacteria break down starch into simpler sugars, such as glucose, thereby helping to recycle nutrients and supporting the growth of other organisms. Interestingly, amylase is also found in human saliva. When we chew starchy foods like bread or potatoes, amylase begins the digestion process right in our mouths. This shows how similar enzymes can work in both nature and our bodies.

In the environment, amylolytic bacteria play a key role as decomposers. They help break down biodegradable materials, such as starch-based bags, which are more eco-friendly than traditional plastic bags. While plastic can take hundreds of years to decompose, starch-based materials break down much faster thanks to the action of bacteria and enzymes like amylase.

### Comprehension Questions

What do amylolytic bacteria produce?

- Where can these bacteria be found?
- What does the enzyme amylase break down?
- How is amylase in human saliva similar to that in bacteria?
- Why are starch-based bags considered more eco-friendly than plastic bags?
- What role do amylolytic bacteria play in ecosystems?



## Annex 11: Starch and saliva (option 1)

**Objective: Investigation to observe how the enzyme amylase in saliva begins to break down starch.**

### Note for Teachers:

These experiments are proposed as an optional extension activity to deepen understanding of enzymatic digestion. It is not mandatory and can be carried out at the teacher's discretion, depending on available time, resources, and class interest. It is suggested to conduct the experiments according to the IBSE approach ([see Annex 3 – Science as Inquiry](#)) and the 5E model (engage, explore, explain, elaborate, evaluation).

**Investigable question: “How can we verify that the salivary enzyme amylase digests starch?”**

### Structured Inquiry

In structured inquiries, students use the teacher's question and a prescribed procedure. The teacher organizes the class into groups and encourages each group to make hypotheses, predictions, develop their own procedure, and share a common one. The teacher may ask each student to individually elaborate hypotheses, predictions, procedures, and necessary materials, to be shared within their group. The Teacher encourages each group develops its own procedure and shares a common procedure (see format lab journal [annex 4](#)).

### Materials Needed:

- A small piece of bread (or cracker)
- Two transparent cups or test tubes
- Water
- Iodine solution (if available)
- Dropper or spoon

### Procedure:

- Chew the bread for 30 seconds without swallowing.
- Spit the chewed bread into one cup.
- Place an equal piece of unchewed bread into the second cup and add a little water.
- Add a few drops of iodine to both cups.
- Observe the color change.

### Expected Result:

- The chewed bread (with saliva) will show less blue-black color, indicating that starch has been broken down.
- The unchewed bread will turn blue-black, showing the presence of starch.
- Write here what you observed and what it means:

### Conclusion:

Amylase in saliva starts digesting starch into simpler sugars, just like amylolytic bacteria do in nature.



**Annex 12: Starch and saliva (option 2 – IBSE approach)**

**Investigable question:** How can we show that saliva contains an enzyme that breaks down starch?

Materials

- Starch solution
- Saliva (collected hygienically)
- Iodine solution
- 2 test tubes or clear cups
- Droppers
- Timer

Procedure

- Pour only starch into the first test tube.
- Pour starch + saliva into the second test tube.
- Wait 10–15 minutes.
- Add iodine to both test tubes.
- Observe the color change.

Observations

Test Tube	Contents	Color after iodine	Is starch present?	Did amylase act?
1	Starch only			
2	Starch + saliva			

Conclusion

Write here what you observed and what it means:

**Mini Quiz: Decomposers and Amylase**

Instructions: Choose the correct answer.

**What does the enzyme amylase break down?**

- a) Protein
- b) Starch
- c) Fat
- d) Plastic

**Where is amylase found in the human body?**

- a) Stomach
- b) Saliva
- c) Skin
- d) Blood



**Which material is biodegradable thanks to bacteria?**

- a) Plastic bag
- b) Aluminum foil
- c) Starch-based bag
- d) Glass

**What is the role of decomposer bacteria?**

- a) Produce oxygen
- b) Break down organic matter
- c) Cause pollution
- d) Absorb sunlight

**Answer Key:**

- b
- b
- c
- b



## Annex 13 – Nitrogen cycle assessment

### The Nitrogen Cycle

**School Name:** \_\_\_\_\_

**Date:** \_\_\_\_\_

**Student Name:** \_\_\_\_\_

#### Instructions:

Circle the correct answer for each question. Each question has only one correct option.

Lesson 5–VIDEO [The Nitrogen Cycle!](#) 5 min

### Reading – The Nitrogen Cycle

#### What is the nitrogen cycle?

The nitrogen cycle is the natural process through which nitrogen moves from the atmosphere to the soil, into living organisms, and back to the atmosphere. Nitrogen is essential for life – it's used to build proteins, DNA, and chlorophyll. However, atmospheric nitrogen ( $N_2$ ) is in a gaseous form and cannot be directly used by plants. That's where nitrogen-fixing bacteria come into play.

#### Nitrogen-fixing bacteria: the soil superheroes

These bacteria live in the soil or in symbiosis with the roots of certain plants, especially legumes (like peas, beans, lentils). Their job? To convert gaseous nitrogen ( $N_2$ ) into a form that plants can use: ammonia ( $NH_3$ ).

#### The key enzyme: nitrogenase

Nitrogenase is the enzyme that allows bacteria to “break” the  $N_2$  molecule, which is very stable. It's a challenging process that requires a lot of energy and only occurs in the absence of oxygen. In summary:

$N_2$  (atmospheric nitrogen)  $\rightarrow$   $NH_3$  (ammonia) thanks to nitrogenase, ammonia is then transformed into ammonium ions ( $NH_4^+$ ) and nitrates ( $NO_3^-$ ), which plants absorb.

#### A concrete example

Imagine a field of broad beans or common beans. In the roots live Rhizobium bacteria. These fix atmospheric nitrogen and convert it into ammonia. The plant uses nitrogen to grow. When the plant dies, decomposers break down the organic matter into ammonium, which can be reused or converted into nitrates. Eventually, some nitrogen returns to the atmosphere through denitrification.

### 1. What is the role of nitrogen-fixing bacteria in the nitrogen cycle?

- A) Convert nitrates into nitrogen gas
- B) Break down organic matter
- C) Transform atmospheric nitrogen into ammonia
- D) Absorb nitrogen from plants



**2. Which enzyme is responsible for breaking the N<sub>2</sub> molecule?**

- A) Amylase
- B) Nitrogenase
- C) Protease
- D) Lipase

**3. Which form of nitrogen do plants absorb most easily?**

- A) Nitrogen gas (N<sub>2</sub>)
- B) Ammonia (NH<sub>3</sub>)
- C) Nitrates (NO<sub>3</sub><sup>-</sup>)
- D) Nitrogenase

**4. What happens during denitrification?**

- A) Nitrogen gas is fixed into ammonia
- B) Nitrates are converted back into nitrogen gas
- C) Ammonia is absorbed by plants
- D) Organic matter is decomposed

**5. Which plants commonly host nitrogen-fixing bacteria?**

- A) Cereals like wheat and rice
- B) Legumes like beans and lentils
- C) Root vegetables like carrots
- D) Leafy greens like spinach

---

Answer Key

C – Nitrogen-fixing bacteria transform atmospheric nitrogen into ammonia.

B – Nitrogenase is the enzyme responsible for breaking the N<sub>2</sub> molecule.

C – Plants absorb nitrogen most easily in the form of nitrates (NO<sub>3</sub><sup>-</sup>).

B – Denitrification converts nitrates back into nitrogen gas.

B – Legumes commonly host nitrogen-fixing bacteria like Rhizobium.

---



## Annex 14: Final Quiz

**School Name:** \_\_\_\_\_

**Date:** \_\_\_\_\_

**Student Name:** \_\_\_\_\_

### Instructions:

Circle the correct answer for each question. Each question has only one correct option.  
Crops and Biodiversity

### 1. What is the main agronomic benefit of legumes like lentils and chickpeas?

- A. They only grow in sandy soils
- B. They require a lot of irrigation
- C. They produce sugar-rich fruits
- D. They fix atmospheric nitrogen into the soil

### 2. Which practice improves soil structure and reduces erosion?

- A. Removing all biomass after harvest
- B. Growing only wheat every year
- C. Using intensive chemical fertilizers
- D. Planting cover crops

### 3. Why is it useful to alternate cereals and legumes in crop rotation?

- A. To make the soil more acidic
- B. To increase sugar production
- C. To improve fertility and reduce diseases
- D. To reduce biodiversity

### 4. Which of the following is a cover crop useful for green manure?

- A. Corn
- B. Eggplant
- C. Tomato
- D. Clover

### 5. What benefit do hedgerows and wetlands offer in a farm field?

- A. They reduce biodiversity
- B. They increase pesticide use
- C. They attract pollinators and natural predators
- D. They promote erosion

### Answer Key and explanation:

D - They fix atmospheric nitrogen into the soil

- Legumes fix nitrogen thanks to symbiotic bacteria in their roots, improving soil fertility.

D - Planting cover crops

- Cover crops protect the soil, improve structure, and reduce erosion.



C - To improve fertility and reduce diseases

- Alternating cereals and legumes improves fertility, lowers pest pressure, and promotes biodiversity.

D - Clover

-Clover is a cover crop that can be buried to enrich the soil with organic matter.

C - They attract pollinators and natural predators

Explanation: Hedgerows and wetlands create habitats for pollinators and natural predators, enhancing biodiversity and field health.



## Annex 15: Soil Biodiversity Quiz – Living in the Soil

**School Name:** \_\_\_\_\_

**Date:** \_\_\_\_\_

**Student Name:** \_\_\_\_\_

Instructions: circle the correct answer for each question. Each question has only one correct option.

### 1. What is the main role of earthworms in soil ecosystems?

- A) Aerating the soil and recycling nutrients
- B) Producing seeds
- C) Pollinating plants
- D) Filtering water

### 2. Why is soil considered a living system?

- A) It is made of rocks
- B) It hosts a variety of organisms
- C) It changes color over time
- D) It contains minerals

### 3. Which human activity is most harmful to soil biodiversity?

- A) Composting
- B) Planting trees
- C) Pollution and overuse of chemicals
- D) Crop rotation

### 4. What message do the worm and snail characters convey in the comic?

- A) Humans should avoid touching soil
- B) Only farmers need to care about soil
- C) Soil organisms are essential and need protection
- D) Soil is boring and lifeless

### 5. How can young people help protect soil biodiversity?

- A) Use more plastic products
- B) Avoid learning about soil
- C) Practice sustainable gardening and composting
- D) Ignore environmental issues

### Answer Key and explanation

#### 1. What is the main role of earthworms in soil ecosystems?

A) Aerating the soil and recycling nutrients: Earthworms aerate the soil by burrowing and help recycle nutrients by breaking down organic matter.

#### 2. Why is soil considered a living system?

B) It hosts a variety of organisms: Soil is considered living because it hosts organisms like bacteria, fungi, worms, and insects.



3. Which human activity is most harmful to soil biodiversity?

C) Pollution and overuse of chemicals: Pollution and excessive chemical use degrade soil quality and harm its living organisms.

4. What message do the worm and snail characters convey in the comic?

C) Soil organisms are essential and need protection: The comic emphasizes that soil organisms play vital roles and deserve protection from harmful practices.

5. How can young people help protect soil biodiversity?

C) Practice sustainable gardening and composting : Young people can help by composting, reducing waste, and learning about sustainable practices.



## Annex 16 – Printable classroom debate sheet

### CASE STUDIES

The two proposed case studies involve reading the comic Living in the Soil, which the teacher and students can access at the following links.

[1.1 Case Study: Living in the Soil – Exploring Soil Biodiversity Through Visual Storytelling](#)

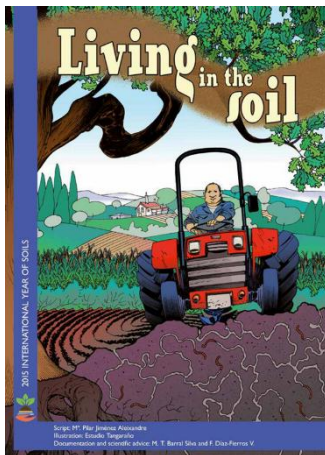
[1.2 Case Study: Living in the soil–The Hidden Heroes Beneath Our Feet: A Soil Biodiversity](#)

[2. Case Study & Classroom Debate: Build or Preserve? The Agricultural Land Dilemma](#)

[living\\_in\\_the\\_soil.pdf](#)

[Living in the Soil – ESDAC – European Commission](#)

[Living in The Soil – Comics – 2 | PDF](#)



“A snail, a worm and a group of young people are some of the characters who star in ‘Living in the Soil’, a comic produced in the context of ‘The International Year of Soils’ that aims to raise awareness about the most significant environmental and social issues related to soil and its need for protection.

Through some 60 sketches, the authors report various aspects of the characteristics, functions and implications related to the use of this non-renewable resource.

It reflects both the view of humans and the living organisms that inhabit soil. The comic, which is conceived as an educational resource, is aimed both at children and the general public and for students at all educational levels”.

### Case Study 1.1: Living in the Soil – Exploring Soil Biodiversity Through Visual Storytelling

#### Note for teacher

**Overview:** This case study is based on the comic Living in the Soil, created by the European Soil Data Centre (ESDAC) for the International Year of Soils. It uses engaging illustrations and storytelling to highlight the critical role of soil organisms in sustaining life and ecosystems.

**Setting:** A classroom or community workshop focused on environmental education (targeting students aged 10–16).

**Problem:** Soil is often overlooked as a living system. Its degradation—caused by pollution, erosion, and unsustainable farming—threatens biodiversity and ecosystem services. Public awareness of soil’s importance remains low.

**Action Taken:** The comic introduces characters like a worm and a snail who guide readers through the underground world. They explain:

- How earthworms improve soil structure and fertility.
- The role of microbes in nutrient cycling and plant health.
- The impact of human activities on soil life.

#### Educational Strategy:

Use the comic as a visual aid in lessons on ecosystems and sustainability.

Facilitate discussions on soil conservation and biodiversity.

Encourage students to observe soil organisms in their local environment.



### Results:

Students demonstrate increased understanding of soil functions.

Greater interest in environmental stewardship and sustainable practices.

Teachers report improved engagement through visual storytelling.

### Objectives:

- Understand the role of soil organisms in ecosystem health.
- Explore human impact on soil biodiversity.
- Reflect on personal and collective responsibility for soil conservation.

Class discussion guide: the comic “Living in the Soil” is a useful discussion guide that can be used by teachers to stimulate curiosity, critical thinking, and environmental awareness. It can be powerful tools for science communication.

### **Opening Questions (Warm-Up)**

- What do you think lives in the soil?
- Have you ever looked closely at soil in a garden or forest? What did you notice?
- Why do you think soil is important for life on Earth?

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### **Comic-Based Discussion**

#### **Character Perspectives**

- How do the worm and snail describe their lives underground?
- What emotions or attitudes do they express about human activity?
- Soil as a Living System
- What makes soil “alive”?
- What are some examples of organisms mentioned in the comic?
- Human Impact
- What threats to soil health are shown or implied in the comic?
- How do farming, pollution, or construction affect soil biodiversity?

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#### **Real-World Connections**

- Can you think of any local places where soil might be at risk?
- What sustainable practices could help protect soil in your community?
- How does soil health relate to climate change, food production, or water quality?
- Critical Thinking Prompts
- If soil organisms could speak to humans, what message would they share?
- Should soil be considered a natural resource like water or air? Why or why not?
- What role can young people play in protecting soil?

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#### **Optional Activities**

- Creative Writing: Write a short story from the perspective of a soil organism.
  - Soil Observation: Collect a small soil sample and examine it with magnifying glasses.
  - Poster Design: Create a visual campaign to raise awareness about soil biodiversity.
- 



## Case Study 1.2: Living in the Soil- Soil Biodiversity and Ecosystem Health

Title: The Hidden Heroes Beneath Our Feet: A Soil Biodiversity Case Study

Note for teacher

Context:

During the International Year of Soils, the European Soil Data Centre released an educational comic titled Living in the Soil, which follows a worm and a snail as they guide young readers through the underground world of soil. This comic serves as a creative tool to raise awareness about the vital role of soil organisms in maintaining ecosystem balance.

Challenge:

Soil degradation due to intensive agriculture, pollution, and urbanization threatens the biodiversity of soil organisms. Many people are unaware that soil is a living system, home to billions of microorganisms and invertebrates that support plant growth, water filtration, and carbon storage.

Intervention:

The comic introduces readers to the concept of soil as a dynamic habitat. Through storytelling and illustrations, it explains:

The role of earthworms in aerating soil and recycling nutrients.

How microorganisms break down organic matter and support plant roots.

The importance of maintaining soil structure and organic content.

Outcomes:

Increased public awareness of soil biodiversity.

Educational adoption in schools across Europe.

Encouragement of sustainable practices such as composting, crop rotation, and reduced chemical use.

Lessons Learned:

Visual storytelling is a powerful tool for environmental education.

Soil organisms, though invisible to most, are essential to life above ground.

Protecting soil biodiversity is key to food security and climate resilience.

## Soil Biodiversity Quiz (with Answer Key)

Instructions: Choose the correct answer for each question. Circle only one option per question.

### 1. What is the main role of earthworms in soil ecosystems?

- A) Aerate the soil and recycle nutrients
- B) Produce seeds
- C) Pollinate plants
- D) Filter water

### 2. Why is soil considered a living system?

- A) It is made of rocks
- B) It hosts a variety of organisms
- C) It changes color over time
- D) It contains minerals



### 3. Which human activity is most harmful to soil biodiversity?

- A) Composting
- B) Planting trees
- C) Pollution and excessive use of chemicals
- D) Crop rotation

### 4. What message do the earthworm and snail characters convey in the comic?

- A) Humans should avoid touching soil
- B) Only farmers should care about soil
- C) Soil organisms are essential and must be protected
- D) Soil is boring and lifeless

### 5. How can young people help protect soil biodiversity?

- A) Use more plastic products
- B) Avoid learning about soil
- C) Practice sustainable gardening and composting
- D) Ignore environmental issues

#### Answer Key

- A) Aerate the soil and recycle nutrients  
Earthworms play a crucial role in improving soil structure and fertility.
- B) It hosts a variety of organisms  
Soil is teeming with life—microbes, insects, fungi, and more.
- C) Pollution and excessive use of chemicals  
These practices disrupt soil ecosystems and harm biodiversity.
- C) Soil organisms are essential and must be protected  
The comic likely emphasizes the importance of caring for soil life.
- C) Practice sustainable gardening and composting  
Young people can make a big impact through eco-friendly habits.

#### Printable Classroom Debate Sheet

#### Case Study 2: Build or Preserve? The Agricultural Land Dilemma

##### Learning Objectives

- Develop critical thinking and persuasive speaking skills
- Understand the ecological value of soil and land use
- Reflect on the intersection of politics, environment, and citizenship

##### Context

In a small town, a private citizen wants to build a house on land currently designated for agricultural use. Neighbors oppose the plan, arguing the land should be preserved for farming and biodiversity. The environmental officer supports keeping the land agricultural, while the mayor is inclined to approve the construction permit—fearing he might lose votes in the upcoming election.



### Debate Roles

Assign students to one of the following roles:

- The Citizen: Defends the right to build a home on private land.
- The Neighbors: Advocate for protecting the land for food production and ecological balance.
- The Environmental Officer: Presents scientific and ecological arguments against construction.
- The Mayor: Balances political pressure, economic development, and environmental concerns.
- The Moderator: Facilitates the debate and ensures fair participation.

### Guiding Questions

- Should agricultural land be used for private housing?
- What are the environmental consequences of soil sealing and urban expansion?
- Are there sustainable alternatives to building on fertile land?
- What responsibilities do local governments have in protecting natural resources?
- How does political pressure influence environmental decision-making?

### Extension Activities

- Research similar land-use conflicts in your region.
- Explore types of soil and their designated uses.
- Write a short position paper defending your group's stance.

### Debate Evaluation Rubric

Criteria	Excellent (4)	Good (3)	Fair (2)	Needs Improvement (1)
<b>Clarity of Argument</b>	Clear, logical, well-supported	Mostly clear and relevant	Some clarity, weak support	Unclear or off-topic
<b>Use of Evidence</b>	Strong use of facts and examples	Some relevant evidence	Limited or vague evidence	No evidence used
<b>Engagement &amp; Delivery</b>	Confident, persuasive, respectful	Mostly confident and clear	Uneven delivery or tone	Unprepared or disengaged
<b>Team Collaboration</b>	Excellent coordination and teamwork	Good collaboration	Some teamwork issues	Poor coordination
<b>Responsiveness</b>	Thoughtful replies to opposing views	Some engagement with others	Minimal interaction	No response to others



## Annex 17: Bibliography

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