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Testing Microbial Cleanup in Real Ecosystems: How Temperature Affects Microbial Activity in



BIOS4YOU
AR 2.0

BIO-INSPIRED STEM TOPICS FOR ENGAGING YOUNG GENERATIONS
THANKS TO THE USE OF AUGMENTED REALITY

Project Number: KA220-BW-23-30-126516

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Introduction

Microorganisms play a vital role in maintaining the balance of natural ecosystems by breaking down pollutants and recycling nutrients. Some bacteria and fungi can biodegrade harmful substances, such as oil, plastic, or heavy metals, transforming them into harmless compounds. However, the efficiency of these microbial cleanup processes depends heavily on environmental factors, especially temperature.

In this AR-based exercise, students explore how temperature influences the ability of microbes to clean pollutants in aquatic or terrestrial ecosystems. Using the Delightex platform, they will observe and interact with 3D models of polluted ecosystems, visualizing how microbial activity changes under different thermal conditions. The experience highlights the connection between biological processes, environmental science, and climate change, showing how rising temperatures can either accelerate or inhibit natural bioremediation.

Through interactive exploration, students will simulate real-world environmental conditions, analyze how microbial metabolism responds to temperature changes, and understand the delicate balance between ecosystem health and climate dynamics. By linking biology, chemistry, and environmental engineering, this exercise inspires students to view microbes not just as microscopic organisms but as powerful allies in ecological restoration and sustainability.

This document consists of the following points:

- Information about AR technology
- How to define AR exercise thanks to the template:
 - General information
 - Pedagogical specifications
 - Technical specifications



General information

<p>Name of the exercise:</p>	<p>Testing Microbial Cleanup in Real Ecosystems: The Role of Temperature in Bioremediation</p> <p><i>This AR exercise allows students to explore how temperature variations affect the performance of microbes in breaking down environmental pollutants.</i></p>
<p>Description of the exercises:</p>	<p>Through interactive 3D visualizations, learners can manipulate the temperature settings of a polluted ecosystem (e.g., an oil-contaminated river or soil patch) and observe corresponding changes in microbial growth rate, enzyme activity, and pollutant degradation speed.</p> <p>The simulation includes multiple scenarios—such as cold, moderate, and high-temperature environments—allowing students to compare how microbes respond under each condition. Animated overlays visualize metabolic acceleration, oxygen consumption, and pollutant concentration reduction in real time.</p> <p>By the end of the activity, students will understand how climate and temperature directly influence the efficiency of microbial cleanup, connecting biological science with real-world environmental management.</p>
<p>Participants:</p>	<p>The exercise is designed for individual learners or small groups (2–4 students).</p> <p>Group work is recommended to encourage data discussion, hypothesis formation, and collective analysis.</p>



Participants' age
range:

Minimum 15-18 years old

Suitable for advanced biology, environmental science, or interdisciplinary STEAM courses.

STEM subject and
specific topic:

STEM Subject: Biology, Environmental Science, Chemistry

Specific Topic: Microbial bioremediation and the influence of temperature on biological cleanup processes in ecosystems

Main challenge (stressful aspect) of the topic:

Students often struggle to connect invisible microbial processes with tangible environmental outcomes.

Understanding how temperature changes affect enzyme activity and microbial metabolism can also be abstract when studied theoretically. The biggest challenge lies in visualizing how climate variables (e.g., temperature rise) influence pollutant degradation rates in real-world conditions.

How AR helps simplify the concept:

- **3D visualization** of microbes, pollutants, and environmental layers makes abstract biological processes visible.
- **Temperature slider** allows users to adjust conditions and instantly observe the resulting microbial response.
- **Color-coded animations** show microbial population changes and pollutant degradation speed under different scenarios.
- **Real-time data overlays** (e.g., pollutant concentration, oxygen level, degradation rate) make scientific relationships clear and measurable.
- **Interactive cause-and-effect visualization** helps students see how environmental changes impact biological systems.

Pedagogical Aim (Learning Outcomes):

By completing this exercise, students will be able to:

1. Explain the relationship between **temperature** and **microbial activity** in bioremediation.
2. Describe how **enzymatic reactions** drive pollutant breakdown in ecosystems.
3. Understand the impact of **climate factors** on natural cleanup processes.



Gamification
process:

4. Apply **experimental thinking** by testing hypotheses through virtual temperature manipulation.
5. Evaluate how microbes contribute to **sustainability and ecosystem resilience** in the context of climate change.

- **Simulation Mode:** Students manipulate temperature and observe real-time microbial responses.
- **Challenge Mode:** Predict which temperature range will result in the highest degradation efficiency.
- **Scoring System:** Points are earned for accurate predictions and data-based reasoning.
- **Progress Bar:** Tracks student understanding as they identify the optimal environmental conditions for microbial cleanup.
- **Reflection Stage:** Students summarize their findings, connecting the virtual experiment to real-world environmental challenges.

Written or graphic
description of
Augmented info:

The AR scene presents a **polluted aquatic ecosystem** (e.g., river or coastal zone) populated by **3D microbial communities**.

- Microbes are shown attaching to pollutant particles (e.g., oil droplets, plastic fragments).
- Students use an **interactive temperature control** to modify conditions between **0°C and 40°C**.
- Animated overlays visualize the change in microbial metabolism, faster activity in moderate warmth, slowed function in cold, and enzyme denaturation in excessive heat.
- Pop-up panels display **real-time pollutant concentration** and **biodegradation efficiency**.
- Graphs and data tables appear dynamically, summarizing **enzyme performance** and **pollution reduction percentage** for each temperature range.

External (or extra)
tools required

Tablet or smartphone with AR capability and internet connection.

Delightex platform (app or browser version).

Optional worksheet for recording observed data and summarizing results.



Optional video for classroom context: Cleaning Up Pollution with
Microbes | Wednesday Wisdom

Links (video,
images, text online
and so on).

Video: Cleaning Up Pollution with Microbes | Wednesday
Wisdom

Link: <https://youtube.com/shorts/tFTlhX-42FQ?si=IxP4e1gHirsqTfZC>



Pedagogical specifications

Here we will collect information on how to use the exercise in the learning session and the results and benefits of using it, from a pedagogical perspective.

[How can this augmented information be used to address a STEAM topic in a more interesting way for students?](#)

Interactive 3D Models

Goal:

Help students visualize how **temperature influences microbial activity** in polluted ecosystems and understand how biological and chemical processes interact to achieve environmental cleanup.

Use:

Students can explore a 3D model of a polluted aquatic ecosystem that includes water layers, sediment, and various microbial communities. When students adjust the temperature control, they immediately see changes in microbial behavior, movement, color, and pollutant breakdown rate. Cold settings show reduced activity, moderate temperatures show optimal cleanup, and high heat causes enzyme denaturation. Pop-up explanations and animated overlays illustrate oxygen use, CO₂ release, and pollutant degradation, turning invisible biological and chemical processes into engaging, observable events that connect biology, chemistry, and environmental science within one STEAM framework.

Interactive Buttons

Goal:

Encourage students to **experiment with environmental variables** and analyze how temperature affects microbial metabolism, efficiency, and pollutant removal.

Use:

Students use buttons and sliders to change variables such as **temperature, pollutant type, and microbial strain**.

Each adjustment triggers animated feedback showing microbial response and pollutant reduction. They compare biodegradation rates through simple charts and try a **Challenge Mode** to find the **optimal temperature** for cleanup efficiency, linking experimentation with gamified learning.



Possible Classroom Session Plan

Introduction (5–7 mins)

Goal: Introduce students to the role of microbes in environmental cleanup and how temperature influences their function.

- Begin with a question: “*Why do oil spills degrade faster in summer than in winter?*”
- Show a short introductory video (e.g., *Cleaning Up Pollution with Microbes | Wednesday Wisdom*).
- Discuss how microbial activity depends on enzyme function and environmental factors such as heat, oxygen, and nutrients.

Main Activity – AR Exercise (30-35 mins)

Testing Microbial Cleanup with Temperature Variation

AR Model Interaction (10–15 mins):

Students access the Delightex AR simulation showing a polluted water body.

Hands-on Exploration:

Adjust temperature using the interactive slider.

Observe how microbial activity and pollutant levels change visually.

Tap microbes to trigger short animations of enzyme reactions (e.g., breaking down oil molecules).

Watch the environment become clearer as cleanup progresses.

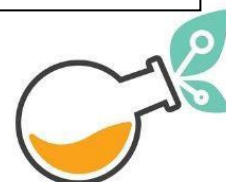
Guided Learning Tasks (10–15 mins):

- Compare results under three scenarios: *Cold (5°C)*, *Moderate (25°C)*, and *High (40°C)*.
- Analyze degradation speed using built-in graphs.
- Discuss the relationship between temperature, enzyme activity, and microbial efficiency.
- Gamified Challenge: “*Find the Sweet Spot*”, determine the optimal temperature for maximum pollutant breakdown, and record your observations.

Conclusion & Recap (10-15 mins)

Goal: Reinforce learning and connect virtual results to real-world bioremediation.

- Project or share student findings to discuss:
 - *Which temperature supported the fastest cleanup?*
 - *What happened when conditions were too cold or too hot?*
 - *How might global warming affect microbial balance in ecosystems?*
- Reflection Task: Students write a short paragraph answering:
“*How do microbes help keep our planet clean, and what environmental factors affect their success?*”
- Conclude by linking the activity to broader STEAM themes, biology (microbial life), chemistry (reaction rates), and environmental engineering (ecosystem restoration), emphasizing how technology supports scientific discovery.



Which pedagogical objectives are addressed through this scenario?

Active Engagement

Students actively explore how temperature influences microbial activity and pollution degradation through hands-on AR simulations. By adjusting environmental conditions and observing immediate visual feedback, they engage in experimental inquiry, testing hypotheses and interpreting real-time results. This immersive process turns abstract biological and chemical interactions into visible, cause-and-effect experiences, fostering curiosity and participation.

Critical Thinking

The exercise promotes critical thinking as students analyze how and why temperature changes affect microbial efficiency. By comparing different environmental conditions, they evaluate cause-and-effect relationships between temperature, enzyme function, and pollutant breakdown, linking their observations to real-world climate and pollution issues. They are encouraged to reason scientifically, identifying patterns, drawing conclusions, and reflecting on environmental implications

Application of Knowledge

Students apply theoretical knowledge of enzymatic activity, metabolism, and environmental science to simulate and interpret bioremediation processes. Through experimentation, they see how temperature modifies biological reaction rates and environmental outcomes, reinforcing core STEM concepts through practical, data-based analysis.

This direct application bridges classroom theory with real-world sustainability challenges, such as climate-driven pollution dynamics.

Multimodal Learning (Visual, Hands-On, Inquiry-Based Learning)

The AR experience integrates visual, interactive, and inquiry-based learning, accommodating diverse learning styles. Students visualize data, manipulate variables, and engage in guided exploration, connecting biology, chemistry, and environmental science in one cohesive activity.

This multimodal approach deepens understanding and retention by transforming abstract STEAM topics into tangible, exploratory experiences.



Which results are expected to be reached with its use?

Enhanced Understanding of Microbial Processes and Environmental Interactions

Students will gain a clear understanding of how temperature affects microbial metabolism and pollutant degradation. By observing real-time AR simulations, they connect enzyme activity and bioremediation efficiency to broader environmental systems.

This visualization helps them see how biological processes contribute to ecosystem recovery and pollution control under changing climate conditions.

Increased Engagement and Interest in STEAM and Environmental Science

The interactive, experiment-based approach increases motivation and curiosity about microbiology, chemistry, and environmental sustainability.

Students experience how digital tools can model real-world ecological processes, encouraging interdisciplinary thinking and greater interest in biotechnology and environmental research.

Improved Retention and Recall of Key Concepts

By linking theoretical biology and chemistry with interactive experimentation, students more easily remember how temperature influences microbial reactions.

The combination of visual cues, animations, and data overlays strengthens conceptual retention and helps them recall cause-and-effect relationships between climate and bioremediation.

Increased Confidence in Applying Scientific and Analytical Thinking.

Through exploration and guided reflection, students gain confidence in applying scientific reasoning and data interpretation to real-world contexts.

They learn to evaluate variables, interpret experimental outcomes, and explain how environmental conditions affect biological systems. This experience fosters critical awareness of how human activities and climate impact the natural cleanup capacity of ecosystems, promoting informed, sustainability-oriented thinking.



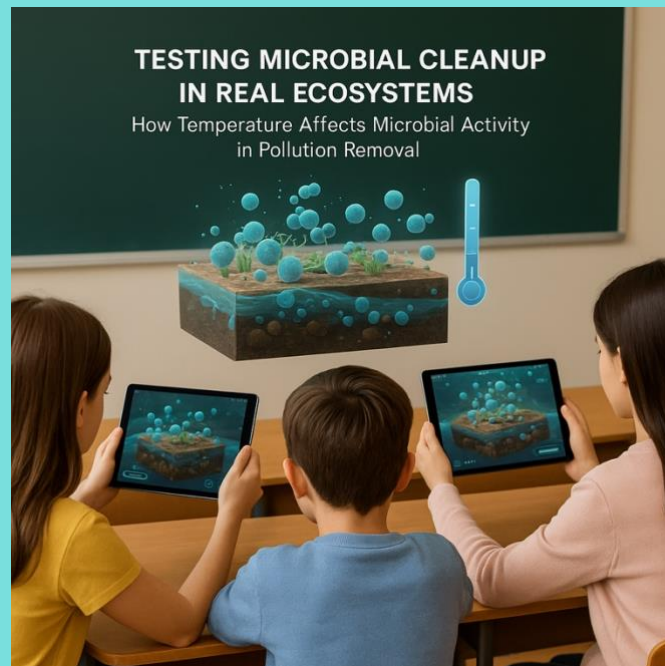
Technical specifications

AR INFORMATION

Technology

Markerless Augmented Reality (AR) using the **Delightex platform**.

If it's needed a marker, description of the marker



Hardware and software needed:

Hardware: PC, smartphone, tablet (for accessing AR content), Camera (for AR functionality), Gyroscope (for AR tracking on mobile devices).

Software: The **Delightex** AR web-based viewer or mobile app, compatible with both **iOS** and **Android**.

Type of Augmented data

- **3D models** of microbes, pollutants, and environmental layers (water, soil, air).
- **Interactive temperature slider** for controlling environmental conditions.
- **Animated overlays** showing pollutant breakdown, microbial movement, and enzymatic reactions.

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Written description of the AR data

- **Color-coded data visualizations** representing activity levels (blue = low, green = optimal, red = overheated/inactive).
- **Pop-up text boxes** explaining biochemical and environmental processes.
- **Dynamic graphs** showing degradation rate and microbial population change over time.

In the AR environment, students see a 3D polluted ecosystem, such as an oil-contaminated river or soil patch.

Microbes are visible as clusters of animated spheres or rod-shaped forms surrounding pollutant particles.

By adjusting the temperature slider, learners observe:

- Changes in microbial motion and population density.
 - Variation in enzyme activity shown by color intensity and degradation rate.
 - Reduction in visible pollutants as bioremediation progresses.
- At high temperatures, enzyme denaturation is depicted by fading or collapsing microbial structures.
- Pop-up panels display numerical indicators such as *pollutant degradation (%)* and *enzyme efficiency*.
- Graphs automatically update to visualize how temperature impacts cleanup performance and ecosystem health.

Additional features:

- **Animated sequence** illustrating the step-by-step process of biodegradation under different temperatures.
- **“Temperature Challenge Mode”** where students predict the optimal range for maximum microbial activity and test their hypotheses.
- **Comparison dashboard** showing performance at cold (5°C), moderate (25°C), and hot (40°C) conditions.
- **“Return to Start” button** allowing students to reset temperature and repeat experiments.
- **Reflective questions** integrated into the interface (e.g., “What happens if the environment gets too warm?”).
- **Short video integration** explaining microbial bioremediation in natural systems.

Scene

Four scenes:



Scene 1 – Introduction: The Polluted Ecosystem

Students see an overview of a contaminated riverbed or soil layer with visible oil or waste particles. Microbes are dormant at low temperature.

Scene 2 – Moderate Temperature (Optimal Activity)

As students raise the temperature, microbial movement intensifies. Pollutants shrink, oxygen bubbles appear, and color overlays indicate active degradation.

Scene 3 – High Temperature (Denaturation)

Further temperature increase causes enzyme breakdown. Microbes fade, pollutants stop degrading, and visual cues show stress in the system.

Scene 4 – Reflection and Data Review

Students view graphs comparing temperature and degradation rate, summarizing findings. Reflection prompts encourage them to interpret the results scientifically.

-

If Image

If Text

What Is Microbial Cleanup?

Microbial cleanup, or **bioremediation**, uses bacteria and fungi to break down pollutants into harmless compounds.

How Does Temperature Affect It?

Temperature influences enzyme activity—too low slows reactions, too high damages enzymes, and moderate levels maximize degradation efficiency.

Why Is It Important?

Understanding this process helps scientists optimize **pollution control and ecosystem recovery**, especially under changing climate conditions.

If video

-

If audio

-



If 3D model



Delightex

<https://edu.delightex.com/FUP-MDG>





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