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9_The Invisible World Inside Us: How Gut Microbes Shape Our Health

BIOS4YOU AR 2.0

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

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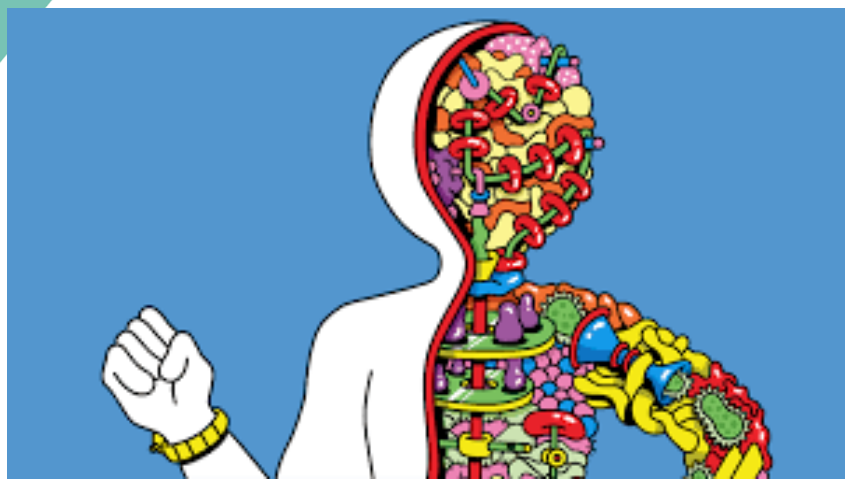

General topic of the learning path	The Invisible World Inside Us: How Gut Microbes Shape Our Health
Specific name of the learning unit	*The Invisible World Inside Us*
Age of the target users	14-18 years
Requirements for the learner	Basic knowledge of cell biology (bacteria, human body systems). Awareness of digestion and nutrition Curiosity about health, medicine, and invisible processes in biology. Openness to teamwork, creative projects, and digital/AR learning tools.
Description of the learning unit	This unit demonstrated that the gut microbiome is not just a hidden curiosity, but a powerful ally for our health. In the Explore phase, students discovered the basic concepts of microbial diversity and function. In the Do phase, augmented reality and interactive activities allowed them to enter the microbiome and observe how microbes digest food, protect health or contribute to disease. In the Improve phase, they reflected on the implications for nutrition, medicine, and everyday life. Thanks to augmented reality, invisible processes became visible and abstract science turned into a practical journey. Students not only gained knowledge about gut microbes, but also developed critical thinking about how to apply this science to personal health and global challenges. The invisible world within us reminds us that we are ecosystems, not individuals. The more we learn to live in harmony with our microbial partners, the healthier and more sustainable our lives can be.
Subject: Parties involved	Subjects: Biology, Health Science, Nutrition, Digital Literacy, Ethics.

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	Parties involved: Students, teachers and optional guest experts (nutritionists, microbiologists, or healthcare professionals).
Keywords	Microbiome, Health, Digestion, Probiotics, Dysbiosis, Nutrition, AR Learning.
Key qualifications, skills and knowledge that can be acquired	Knowledge: Structure and diversity of the gut microbiome. Impact of diet and lifestyle on microbial balance. Skills: Use of augmented reality to visualise invisible biological processes. Design of health-related projects (e.g., microbiome-friendly menus). Scientific teamwork, communication and case study analysis. Critical reflection on ethical, medical and nutritional issues.
Resources and didactic aids used	Digital/AR tools: interactive AR simulations of the microbiome; Merge Cube AR; Google Expeditions AR. Video and media - Websites: • Asknature.org (comparative biomimetics for microbes and ecosystems). • Gut Microbiota for Health. Teaching materials: microscope images, bacteria models, food charts, reflection lab diaries.
Assessment criteria and evaluation	Evaluation combines formative assessment (feedback during AR exercises, reflections) and summative assessment (final presentations, projects, and AR-based assessments).

Introduction

We often think of ourselves as individuals, but inside each of us lives a vibrant community of trillions of tiny organisms: bacteria, fungi, viruses and other microbes. Known collectively as the gut microbiota, these microscopic companions play an extraordinary role in our daily lives. They

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help us digest food, train our immune system, produce essential vitamins, and even influence our mood and brain function.

The human gut microbiome has been called a ‘forgotten organ’ because, although invisible to the naked eye, it works alongside our cells to maintain balance and health. Understanding how gut microbes work opens new doors to medicine, nutrition and even mental wellbeing. This unit takes students on a journey into the hidden world within them, using interactive activities and augmented reality (AR) to bring this microscopic universe to life.

The word ‘microbe’ comes from the Greek *mikros* (small) and *bios* (life). Microbes include bacteria, archaea, fungi, protozoa and viruses. Some live in the soil, others in water, and billions live inside our bodies, silently influencing our health every day.

The existence of microbes was unknown until the invention of the microscope in the 17th century. Dutch scientist **Antonie van Leeuwenhoek** was the first to observe them around 1674, using lenses he had made himself. He called these tiny creatures *‘animalcules’* when he saw them wriggling in a drop of pond water. This was a turning point in science: for the first time, humanity realised that there was a whole invisible world coexisting with us.

Later, in the 19th century, scientists such as **Louis Pasteur** and **Robert Koch** demonstrated that microbes could cause disease, giving rise to the “germ theory”. Pasteur showed that microorganisms were responsible for food fermentation and spoilage and developed the pasteurisation process to make milk safe. Koch, meanwhile, identified the specific microbes responsible for tuberculosis and cholera, laying the foundations of modern microbiology.

But microbes are not just pathogens. Modern research has revealed their essential role in health and ecology. In our intestines, microbes help digest complex plant fibres, produce vitamins, train our immune system and protect against harmful invaders. Today, scientists use advanced DNA sequencing to study the microbiome, discovering connections between

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microbes and conditions such as obesity, depression, and autoimmune diseases

To make this complex world more accessible, students can watch animations showing bacteria breaking down food molecules or microscope images of microbial colonies growing on a Petri dish. Teachers can guide discussions with questions such as, 'If microbes are invisible to the eye, how do we know they exist?' or 'Why do some microbes make us sick while others keep us alive?'

By the end of this phase, students understand that microbes are not only the oldest and most abundant life forms on Earth, but also our constant companions. They are both friends and foes, shaping ecosystems, human history, and our health in ways we are still discovering.

1- Explore:

In the Explore stage, students build their foundation of knowledge about the gut microbiome.

They first learn that the human gut is home to more microbes than there are stars in the Milky Way — around 100 trillion. Most of these microbes live in the large intestine and form complex communities that interact with each other and with our bodies.

Key concepts introduced:

- Composition: Bacteria, fungi, viruses, and archaea coexist in the gut.
- Functions: Gut microbes break down fiber into nutrients, produce vitamins like B12 and K, regulate the immune system, and help defend against harmful pathogens.
- Health Impact: A balanced microbiome supports well-being, while imbalances (called dysbiosis) are linked to obesity, diabetes, allergies, depression, and autoimmune disorders.
- Nutrition: Foods rich in fiber (like fruits, vegetables, and whole grains) and fermented foods (like yogurt, kimchi, kefir) help support healthy microbes.

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- The Gut–Brain Axis: Communication between gut microbes and the nervous system shows how the microbiome can influence stress, mood, and cognitive functions.

Classroom resources can include videos of animations showing how bacteria digest fiber, case studies of probiotic use, and interactive discussions like: “If microbes are invisible, how do we know they exist and what they do?”

By the end of this stage, students have a strong conceptual map of the invisible microbial world and its importance in everyday health.

2- Execute:

At this stage, students cease to be passive learners and begin to act as explorers of the microbiome. Through AR applications, they “shrink” to microscopic size and enter the human gut, where they can observe the vibrant world of trillions of microbes. The AR environment transforms abstract biology into a living, interactive universe.

Extended AR features:

- An interactive 3D model of the gut allows students to zoom in on microbial colonies, rotate them, and see how different species cluster in various parts of the gut.
- Dynamic animations show bacteria breaking down dietary fibre into short-chain fatty acids, which are then absorbed by the intestinal lining and used for energy.
- A “before and after” simulation compares a healthy microbiome with one altered by antibiotics, stress or an unhealthy diet, making the consequences of imbalance immediately visible.

Expanded hands-on exercises:

- AR Mission 1 - Meet the Allies: Students explore a balanced gut microbiome, identifying common beneficial bacteria such as

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Bifidobacteria and Lactobacillus. They observe how these microbes interact and cooperate in digesting food and producing vitamins.

- AR Mission 2 - When things go wrong: Students study a dysbiotic gut, identifying missing beneficial microbes or the proliferation of harmful species. They must then predict the potential health consequences (e.g., poor digestion, inflammation, or a weakened immune system).

Nutritional challenge: Students simulate the effect of adding different foods to the gut: fibre-rich vegetables that increase microbial diversity or sugary processed foods that lead to an imbalance. This shows how diet directly influences the microbial community.

Group project: Working as “dieticians”, groups design a microbiome-friendly menu for a teenager's daily diet. They justify their choices by linking foods to microbial benefits.

Real-world examples:

In Denmark, secondary school students participated in citizen science projects by sequencing their own gut microbiomes and analysing the results with university laboratories.

In Japan, schools have created microbiome-inspired gardens, teaching how both soil and gut microbes contribute to human health.

Expanded feedback collection:

The AR application provides real-time feedback: for example, when students add fibre to the simulation, they can immediately see beneficial bacteria proliferate.

Teachers observe teamwork and creativity, noting how groups design balanced diets or explain their reasoning.

Students keep reflection journals, writing down what surprised them most: Did they realise that microbes can affect mood? Did they expect the diet to change microbial communities so quickly?

This phase ensures that knowledge becomes practice and practice becomes insight.

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3- Enhance:

Here, students go beyond observation to **imagination and application**. The goal is to use what they have learned to reflect on broader implications for health, medicine, and society.

How augmented reality deepens understanding:
With augmented reality, invisible processes become visible. Students can observe a bacterium signalling immune cells to respond to infection, or observe the gut-brain connection as microbial by-products influence neurons. By connecting microscopic processes to real-world health outcomes, augmented reality makes biology more tangible and relevant.

Expanded interactive learning:
Students are guided through debates and scenario creation:

- *Could personalised microbiome-based therapies one day replace antibiotics?*
- *Should schools integrate probiotics and prebiotics into food programmes?*
- *If gut microbes influence mental health, should doctors "prescribe" diets instead of pills?*

These conversations encourage critical thinking, connecting science to ethics and society.

Expanded gamified content:

- **Points and badges** are awarded for successfully completed AR missions, such as correctly identifying the roles of bacteria.
- **Leaderboards** highlight collaboration and creativity during group projects.
- **Missions and levels** guide students from simple tasks (identifying microbes) to complex simulations (building a resilient microbial ecosystem).

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- **Rewards for exploration:** Students are rewarded for proposing innovative nutrition or health strategies inspired by microbiome science.
- **Collaborative assignments:** Groups design a school-wide campaign to promote microbiome health, such as posters on healthy snacks or a digital “gut health challenge” for their peers.

Augmented reality-based assessments:
Instead of a traditional test, students submit augmented reality-enhanced projects. For example, they could create an augmented reality 3D model comparing a healthy and unhealthy microbiome, narrating how diet and lifestyle affect microbial communities. Teachers assess not only accuracy, but also creativity and problem-solving skills.

Conclusion:

This unit demonstrated that the gut microbiome is not just a hidden curiosity, but a powerful ally for our health. In the Explore phase, students discovered the basic concepts of microbial diversity and function. In the Do phase, augmented reality and interactive activities allowed them to enter the microbiome and observe how microbes digest food, protect health or contribute to disease. In the Improve phase, they reflected on the implications for nutrition, medicine, and everyday life. Thanks to augmented reality, invisible processes became visible and abstract science turned into a practical journey. Students not only gained knowledge about gut microbes, but also developed critical thinking about how to apply this science to personal health and global challenges. The invisible world within us reminds us that we are ecosystems, not individuals. The more we learn to live in harmony with our microbial partners, the healthier and more sustainable our lives can be.

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Phase	Description
Explore	- Research and Discovery: Students begin by discovering what microbes are and how they were first observed under early microscopes by pioneers like Antonie van Leeuwenhoek. They learn that trillions of microbes live inside the human gut, forming a community known as the microbiome. These microbes play essential roles in digestion, immunity, vitamin production, and even mental health.
	- Content Development: The content introduces the difference between a balanced microbiome and dysbiosis, connecting microbial health to everyday choices like diet and stress.
	- Needs Analysis: Because microbes are invisible, students often struggle to picture how they work. Visual tools, AR models, and interactive explanations are needed to make abstract processes like fiber digestion or immune regulation clear and relatable.
Execute	- Curriculum Implementation: Students move from theory to practice through AR simulations of the gut microbiome. They can "zoom in" to see bacteria interacting with food molecules, compare healthy and unhealthy guts, and explore how different diets affect microbial balance.
	- Interactive Exercises: Mission 1: Identify beneficial bacteria in a healthy gut. Mission 2: Diagnose problems in an imbalanced microbiome and predict health consequences. Nutrition Challenge: Simulate how fiber-rich vs. high-sugar diets change the microbiome. Group Project: Design a "microbiome-friendly menu" and present it as dieticians.
	- Feedback Collection: AR apps provide instant feedback. Teachers observe teamwork and reasoning during projects. Students write reflections in journals on what surprised them most about microbes' influence on health.
Enhance	- AR Integration: AR tools expand the learning experience by showing otherwise invisible processes — microbes producing vitamins, training the immune system, or signaling the brain. This makes connections between microbiology and personal health clearer.
	- Interactive Learning: Students engage in debates and scenarios
	Gamified Content: Points and Badges: Awarded for completing AR missions. Leaderboards: Celebrate teamwork and creativity. Quests and Levels: Guide students from identifying microbes to building resilient ecosystems. Rewards for Exploration: Extra credit for creative diet or health campaigns. Collaborative Tasks: Groups design a school-wide awareness campaign on microbiome health.
	AR-Based Assessments: Instead of a test, students present AR-based projects — for example, a 3D model comparing healthy vs. dysbiotic microbiomes. Evaluation focuses on scientific accuracy, creativity, teamwork, and the ability to link microbes to real-world health outcomes.

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