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25_Aquaponics: Nature-Based Solutions for the Future



BIOS4YOU
AR 2.0

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

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TABLE OF CONTENTS

Contents

Introduction	2
1- Explore - Introduction to Aquaponics and Nature-Inspired Water Recovery	3
2- Execute:	5
3- Enhance:	5
Conclusion:	6





General topic of the learning path	Aquaponics: Nature-Based Solutions for the Future
Specific name of the learning unit	Aquaponics: Nature-Based Solutions for the Future
Age of the target users	14-18 years
Requirements for the learner	Basic knowledge of biology and ecosystems (producers, consumers, decomposers); curiosity about environmental issues; ability to work in groups; openness to using digital and AR tools.
Description of the learning unit	This unit introduces students to the scientific, technical, and ecological principles behind aquaponics , an integrated system combining aquaculture (fish farming) and hydroponics (soilless plant cultivation). Learners explore the fragility of ecosystem balance, experiment by building a mini aquaponics system, and use Augmented Reality (AR) to visualize nutrient cycles and design sustainable eco-buildings. The methodology follows the Explore – Execute – Enhance framework, guiding students from research and discovery, through hands-on creation, to reflection and innovative applications.
Subject: Parties involved	Biology, Environmental Science, Engineering/Technology, Design and Architecture; Teachers as facilitators; Students as researchers, designers, and problem-solvers.





Keywords	Aquaponics, Ecosystem Balance, Nature-Based Solutions, Sustainability, Circular Systems, Augmented Reality, Bio-Inspired Design.
Key qualifications, skills and knowledge that can be acquired	Knowledge: ecosystem dynamics, AR applications in science. Skills: problem-solving, teamwork, experimental design, data collection, design-based learning, creative use of AR. Qualifications/Competences: ability to apply sustainability principles, critical thinking, digital literacy, interdisciplinary connections (biology + engineering + design).
Resources and didactic aids used	Case study (<i>The Dying Lake</i>), role-play activity, lab materials for mini aquaponics systems (containers, pumps, plants, fish), digital lab journals, AR apps for visualizing nutrient cycles and eco-building design, gamification tools (points, badges, leaderboards).
Assessment criteria and evaluation	Evaluation is based on: Knowledge, Practical skills, Collaboration Creativity & Innovation, AR & Digital Use, Engagement.

Introduction

In the 21st century, global population growth has drastically increased pressure on natural resources like water and soil. Industrial agriculture and aquaculture have contributed significantly to water pollution, releasing high amounts of nitrogen, phosphorus, and chemical fertilizers into aquatic ecosystems. As a result, freshwater resources are under threat, biodiversity is declining, and environmental balance is at risk.





To tackle these challenges, international organizations and researchers are increasingly turning to Nature-Based Solutions (NBS): sustainable practices inspired by natural processes that improve environmental quality while reducing human impact. One of the most promising among these is aquaponics, an integrated system that combines aquaculture (fish farming) with hydroponics (soilless plant cultivation). In aquaponics, nutrient-rich water from fish tanks is recycled through plant beds where it gets naturally filtered.

This learning unit introduces students aged 15–18 to the scientific, technical, and ecological principles behind aquaponics. Through experimental setups, augmented reality (AR), and design-based learning, students explore how biology and engineering can intersect to develop sustainable water reuse systems and inspire eco-friendly architectural solutions.

1- Explore - Introduction to Aquaponics and Nature-Inspired Water Recovery

Aquaponics is an innovative food production system that combines aquaculture—the farming of fish—with hydroponics, the soilless cultivation of plants. In this closed-loop cycle, the waste produced by fish becomes a natural fertilizer for plants, while the plants filter and clean the water before it returns to the fish tanks. This creates a self-sustaining ecosystem where each component benefits the other, reducing the need for chemical fertilizers and minimizing wastewater. According to research, aquaponics can reduce water use by up to 90% compared to conventional soil farming, since the water is constantly recycled and only small amounts are lost through evaporation or plant transpiration (Go Green Aquaponics, 2024; CalPoly Research, 2022).

At the heart of aquaponics is the nitrogen cycle, a natural biological process that makes waste usable instead of harmful. Fish excrete





ammonia, which in high concentrations is toxic. Beneficial bacteria living in the system—mainly *Nitrosomonas* and *Nitrobacter*—transform this ammonia first into nitrites, and then into nitrates, which plants can safely absorb as nutrients. This transformation not only supports plant growth but also purifies the water, creating a continuous loop of nutrient recycling that keeps both fish and plants healthy (Hawaii University Aquaponics Program, 2023).

The concept of aquaponics is a practical application of a broader idea: Nature-Based Solutions (NBS). NBS are approaches that draw inspiration from natural processes and ecosystems to solve modern environmental challenges. Instead of relying on industrial or chemical interventions, NBS mimic how nature regulates cycles, filters resources, and maintains balance. For example, wetlands naturally clean water, green roofs absorb rain and reduce runoff, and aquaponics reuses water by replicating the relationships found in natural ponds or rivers. By implementing NBS, communities not only reduce environmental impact but also increase resilience and biodiversity (European Commission, 2021; FAO, 2021).

Taken together, these concepts highlight the efficiency and sustainability of aquaponics. It shows how water can be reused rather than wasted, how bacteria act as invisible partners in food production, and how bio-inspired systems can replace industrial methods that damage the environment. More than a farming technique, aquaponics is an educational model of how humans can work with, rather than against, natural cycles—an approach increasingly vital in addressing global challenges like climate change, water scarcity, and sustainable urban living.

AR Activities:

Real-world case studies: water contamination by fertilizers, ecosystem degradation.





AR experience: simulate a water cycle with vs. without human intervention. Students interact with a virtual ecosystem and observe pollution patterns and nature-based remediation.

2- Execute:

Curriculum Implementation

Learners move from theory to practice by **building mini aquaponics systems**. In small groups, they design and assemble containers, pumps, fish tanks, and plant beds. Each team experiments with different plant species, system layouts, and water circulation strategies.

The **AR application** acts as a digital guide: overlaying step-by-step setup instructions, comparing learners' systems with a virtual model, and simulating potential problems (e.g., low oxygen or pH imbalance).

Interactive Exercises

Hands-on tasks are framed as **bio-inspired design challenges**:

- Ensuring oxygen supply for fish.
- Testing plant species suited to nutrient-rich water.
- Optimizing water circulation.

Worldwide classroom examples show inspiration: Hawaiian schools use aquaponics for biology lessons, while European schools use AR to model nitrogen cycles.

Feedback Collection

Students record their progress in **digital lab journals**, noting pH levels, plant growth, and fish behavior. AR tools provide **instant feedback**, flagging issues when data falls outside expected ranges. Teachers facilitate reflection sessions where groups share results, compare findings, and refine their systems collaboratively.





3- Enhance:

The final phase is dedicated to reflection and envisioning the future. Students compare their systems: which ones work best? What difficulties did they encounter? What improvements would they suggest?

Creativity takes shape through an augmented reality activity: they design an “eco-building” – a building of the future that integrates aquaponics systems to produce food and purify water. Thus, aquaponics leaves the laboratory tank and becomes a concrete idea of sustainable architecture.

The final discussion links the experience to the Sustainable Development Goals (SDGs): how can aquaponics help ensure clean water, healthy food and resilient cities? What are the limitations of this technology?

Conclusion:

At the end of the course, students saw with their own eyes that nature already has the solutions: its closed cycles, in which nothing is lost and everything is transformed, are models from which to learn.

Aquaponics thus becomes more than a technique: it is a metaphor for balance. Fish, bacteria and plants show how collaboration and interdependence can generate sustainability.

The final message is clear: sustainability is not a distant dream, but a concrete possibility. Scientific knowledge, technology and creativity are tools in the hands of the younger generation to imagine a different world. And every student can become part of this change.





References and Resources

Phase	Description
Explore	<p>- Research and Discovery: Learners begin by investigating the global environmental challenges of the 21st century. Rapid population growth and industrial agriculture have increased pressure on freshwater and soil resources, while the overuse of fertilizers has disrupted ecosystems worldwide. Through narrative case studies such as <i>“The Dying Lake”</i>, students see how ecological balance can collapse when nitrogen and phosphorus accumulate in water systems.</p> <p>They also explore the fundamental idea of an ecosystem: a delicate balance between producers (plants), consumers (animals), and decomposers (bacteria). They realize that in nature, nothing is wasted—everything is recycled in continuous cycles of energy and nutrients.</p>
	<p>- Content Development: Key content focuses on Nature-Based Solutions (NBS) as strategies inspired by ecological processes. Learners are introduced to aquaponics as a practical example of NBS: fish produce waste, bacteria convert it into nutrients, and plants absorb those nutrients while cleaning the water. This closed-loop system mirrors natural balance and demonstrates how humans can design sustainable food production.</p> <p>To make invisible processes visible, an Augmented Reality (AR) model is introduced. With AR, learners can explore nutrient flows, watch bacteria “at work,” and visualize how plants filter water.</p>
	<p>- Needs Analysis: Through reflection and class discussion, students identify the need for food systems that are both productive and sustainable. This analysis frames aquaponics not only as a technical innovation but as a response to global environmental and social challenges.</p>
Execute	<p>- Curriculum Implementation: Learners move from theory to practice by building mini aquaponics systems. In small groups, they design and assemble containers, pumps, fish tanks, and plant beds. Each team experiments with different plant species, system layouts, and water circulation strategies.</p> <p>The AR application acts as a digital guide: overlaying step-by-step setup instructions, comparing learners’ systems with a virtual model, and simulating potential problems (e.g., low oxygen or pH imbalance).</p>
	<p>- Interactive Exercises: Hands-on tasks are framed as bio-inspired design challenges:</p> <ul style="list-style-type: none"> ● Ensuring oxygen supply for fish. ● Testing plant species suited to nutrient-rich water. ● Optimizing water circulation. <p>Worldwide classroom examples show inspiration: Hawaiian schools use aquaponics for biology lessons, while European schools use AR to model nitrogen cycles.</p>
	<p>- Feedback Collection: Students record their progress in digital lab journals, noting pH levels, plant growth, and fish behavior. AR tools provide instant feedback, flagging issues when data falls outside expected ranges. Teachers facilitate reflection sessions where groups share results, compare findings, and refine their systems collaboratively.</p>
Enhance	<p>- AR Integration: At this stage, AR deepens understanding by allowing learners to manipulate and test complex processes. They can zoom in on bacterial activity, simulate the collapse of one part of the system, and immediately see the ripple effects on the entire ecosystem.</p>
	<p>- Interactive Learning: Students expand their vision by using AR to design eco-buildings of the future, integrating aquaponics into sustainable architecture. This interdisciplinary activity combines biology, engineering, and design thinking, making learning both creative and applied.</p>





Gamified Content:

- **Points and Badges:** awarded for accurate data collection, creative solutions, or system improvements.
- **Leaderboards:** track group progress, fostering healthy competition.
- **Quests and Levels:** each challenge—balancing nutrients, optimizing water flow, or boosting plant growth—unlocks the next level.
- **Rewards for Exploration:** extra credit for innovative approaches, such as testing unusual plants.
- **Collaborative Gamified Tasks:** cross-team missions where groups share resources or solve shared system challenges.

AR-Based Assessments:

- In AR simulations, learners diagnose failing aquaponics systems and “repair” them by adjusting conditions.
- Interactive quizzes embedded in AR test knowledge of cycles, ecosystems, and design strategies.
- Students are evaluated not only on knowledge recall but on their ability to apply solutions in a virtual-physical hybrid environment.





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