UBC Geering Up
Engineering Outreach

Grow Your Own Algae

Subject:	Grade:	Duration:
Science	4-7	1–2 hours to set up, plus ongoing observations over 2–3 weeks
Lesson Overview	Students get to discover how tiny microscopic plants can remove nutrients from polluted water. They will then engineer a system to remove pollutants faster by changing the environment for the algae.	

Curriculum Ties (in addition to satisfying multiple core competencies):

Science:

- Grade 3: *Biodiversity in the local environment*
- Grade 4: *All living things sense and respond to their environment*
- Grade 5–7 Curricular Competencies:
  - Questioning and Predicting
  - Planning and Conducting
  - Processing and Analyzing Data
  - Evaluating and Communicating
  - Applying and Innovating

Big Ideas:

- Living things are diverse and interact with their ecosystems
- Science relies on evidence and tools to understand the world
- Human actions can affect the environment and living systems

ADST Core Competencies:

- ***Communication:*** **E.g. Collaborating:** Share progress while making sure to increase feedback and collaboration.

- ***Thinking:*** **E.g. Critical and Reflective Thinking**: Screen ideas against criteria and constraints first, students will brainstorm and think consciously about their decisions before executing their plan.
- ***Personal & Social:*** **E.g. Social Responsibility:** Evaluate the influences of land, natural resources, and culture on the development and use of tools and technologies on the construction of their tower

Content Objectives

Students will be able to:

- Explain how algae use nutrients in water to grow
- Identify signs of microbial growth through observable changes in water clarity and color
- Understand the ecological consequences of excess nutrients (eutrophication)
- Experiment with variables (light, temperature, nutrients) to affect growth rates
- Analyze how environmental engineers mimic natural processes to treat wastewater

Materials & Equipment Needed

Consumables:	Non-Consumables:
• Fish tank or large glass container • Samples of lake or river water (collected in advance if needed) • Artificial light source or sunny windowsill	• 1 small clear soda bottle (approx. 591 ml) • 1 larger glass container or mason jar • Liquid plant fertilizer (for simulating nutrient pollution) • Coffee filters • Spoon • Ruler or measuring tape • Notebook or digital journal

Lesson & Activity

<table>
<tr><th>Lesson Stages</th><th>Learning Activities</th></tr>
<tr><td>Introduction</td><td>The Problem of Polluted Water

Begin with a discussion:

What happens when fertilizer, animal waste, or other pollutants enter our lakes or streams?
What is eutrophication, and why is it harmful to fish and aquatic ecosystems?

Introduce the role of environmental engineers in wastewater treatment.

Engineers often use natural microbes like algae to remove nutrients from water.
This process mimics nature but in a controlled setting.

How do the nutrients in wastewater affect microbes? (Answer: The microbes, like algae, use the nutrients to grow.)

Challenge: You are environmental engineers tasked with cleaning a polluted stream using algae. You must design a system that helps algae grow and remove as many nutrients as possible.

Environmental Engineers play a critical role in protecting the environment and public health by developing wastewater treatment systems that use microbes to break down dangerous contaminants and pollutants. They must consider factors such as pH and temperature when they design systems to remove nutrients from wastewater.

Collect samples from a local lake or river. One 591 ml soda bottle per student group (this can be done in advance by the teacher if
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	needed). Fiter each water sample through coffee filters and store samples in fridge until activity is ready to start.

Activity	**Setting Up the Algae Tank**
	1. Filter the water samples using coffee filters to remove debris.
	2. Prepare the base tank:
	    ○ Fill the tank ¾ full with tap water
	    ○ Add 10 ml of liquid fertilizer per liter of water (simulate runoff)
	    ○ Add 20 ml of lake/river water per liter (to introduce native algae/microbes)
	    ○ Mix and place in well-lit location
	    ○ Use a spoon to mix contents in the tank.
	    ○ Place the container on a window sill or near some artificial lights.
	3. Each group prepares their own algae container (bottle or mason jar) using water from the base tank. Label and set aside in similar conditions.
	
	Observing and Experimenting
	Throughout the following weeks, students:
	• Record daily/weekly observations on:
	    ○ Water color
	    ○ Algae buildup
	    ○ Smell or visible particles
	• Ask and investigate questions, such as:
	    ○ What happens if we move the container to a darker spot?
	    ○ Does temperature affect algae growth?
	    ○ Can we grow more algae with more fertilizer?

Assessment tool: Students can track the amount of light passing through the bottle using a flashlight behind the container and a white paper. Less light = more algae growth.

The activity takes a few weeks. The algae species go through all the growth phases.

Scientific Thinking & Discussion Prompts

Questions to guide inquiry:

- What nutrients do algae need to grow?
- What happens when algae die?
- How does this relate to real-world water pollution problems?
- What is in the water collected from the stream or lake? Why are we taking that water sample and putting it in the tank?
    - (Answer: The water sample contains all sorts of organisms naturally present in water bodies. Usually these organisms are kept in check by natural limitations in nutrients, food sources and climate. Of these organisms, we are hoping to select for some algae species.)
- Why is the water turning green?
    - (Answer: In large quantities, we can see algae in water because as the algae begin to thrive, they multiply and cause the water to turn green.)
- Near the end of the experiment: Why is the green color vanishing from the tank?
    - (Answer: The nutrients in the tank have all been used up. Now the algae are starting to die.)
- What tools can we use to measure growth?
    - (Answer: Engineers use the color change as a way to measure growth. They send light through the container and measure how much is absorbed by all the cells. The more light that is absorbed, the more algae we have growing in the container.)

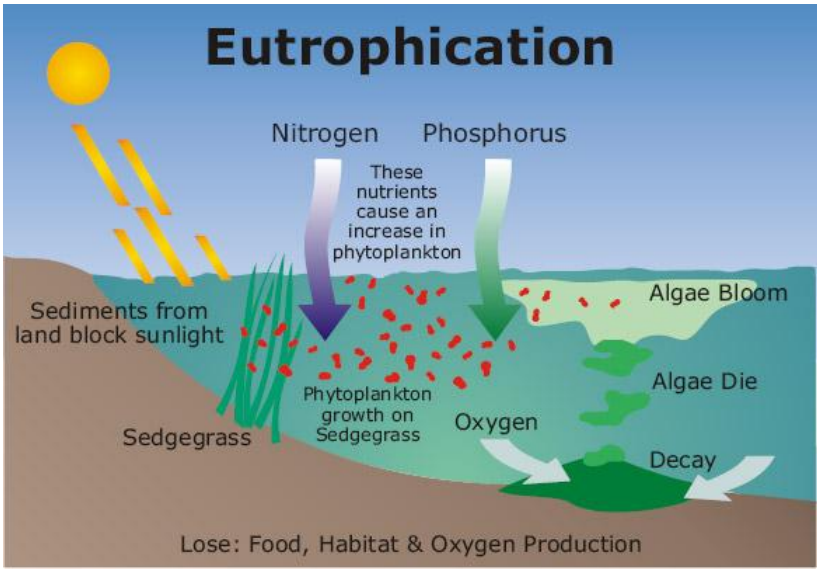
Closure	Have students analyze and interpret their results. • Did any changes speed up or slow down algae growth? • Which containers had the most/least success, and why? Facilitate a reflection: • How can we apply what we learned to real-world solutions? • Why is it important to treat wastewater before it enters natural water bodies? Optional: Ask students to design a diagram of an ideal algae-based treatment system.
Step Ups & Step Downs	Step Down (Grades 4–5): • Focus on color changes and simple journaling of observations • Skip experimental variables; all containers stay under same conditions Step Up (Grades 6–7): • Let students test different variables (light, nutrients, temperature) • Have groups calculate growth rates based on turbidity/light absorption • Use formal lab write-ups and encourage independent investigation

Background Knowledge

Wastewater's Impact on the Environment

When raw wastewater enters a river or lake, it throws off the natural balance of that system. The introduction of large quantities of organic compounds as well as nutrients enables some organisms to grow uncontrolled. It is similar to dumping tons of food on a very hungry community.

The addition of wastewater represents a physical change to the ecosystem, which has a direct impact on microbial population: the organisms that can use organic molecules and nutrients for growth start to thrive. Usually, bacteria and algae are the only organisms that benefit from the influx of wastewater. This explosion of microbial life is called **eutrophication**.



The change in color of the water provides observers with empirical evidence that the wastewater input results in the booming microbial population. Most bacteria, just like us, require oxygen to consume organics. Thus, as they begin consuming what is in the wastewater they also begin consuming all of the oxygen in the water.

Larger organisms like fish and water insects, which are vital to natural ecosystems, require dissolved oxygen in the water to survive. As the oxygen is depleted, these larger organisms begin to die off.

A similar problem is encountered when algae populations begin to explode due to the nutrients in wastewater. However, algae add oxygen to the water, at least at the beginning. What usually happens is that the algae population explodes to the point at which they consume all of the nutrients in the wastewater and begin to die off due to a lack of nutrients. As they die, they become food to bacteria, which consume all the oxygen in the water. Both pathways lead to the eventual destruction of a habitat. That is why wastewater treatment focuses on the removal of the organics and nutrients from wastewater.

Mimicking Nature

How exactly do we remove the organics and nutrients from wastewater? The answer might be surprising! Why don't we mimic the same process that occurs in nature but in a controlled environment? We know that the microbes are breaking down the organic molecules and we know that other microbes can use the nutrients to grow, thereby removing the nutrients from the water. That is exactly what environmental engineers do to treat wastewater.

Environmental engineers create the perfect environment for microbes to thrive and break down as many organics as possible.

Diversity of Microbial Life

What about the really strong types of wastewater? What about the exotic compounds found in some high-strength wastewaters? The fact that such a large variety of microbes exist on this planet is of great benefit to humanity. Each has found a niche habitat, or unique environment, in which to dwell.

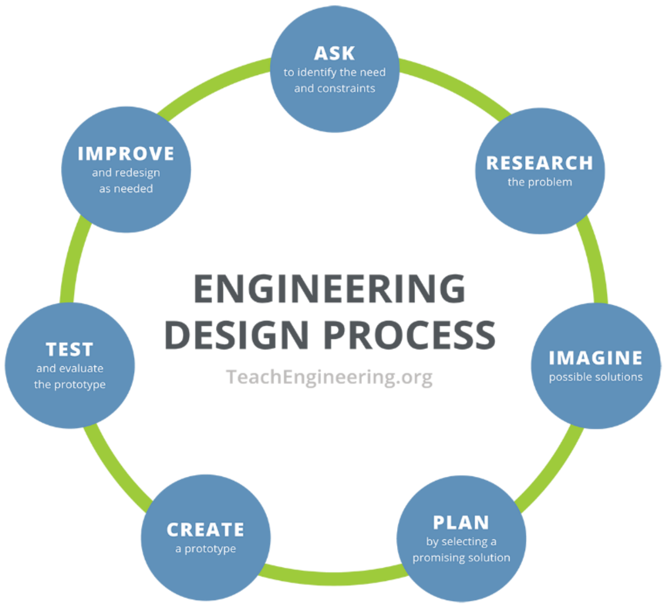
These habitats range from places of near zero pH to places with pH 10, environments that are typically colder than freezing to places like thermal vents that are near boiling temperature. In addition to being able to withstand harsh environments, microbes can degrade a variety of compounds. Some organisms can readily consume materials that are toxic to most others, such as radioactive material and arsenic (used for genetic material). This diversity allows environmental engineers to select the exact organisms that can withstand the conditions of a specific wastewater and be able to degrade the specific types of organics in that wastewater.

Why are some organisms able to degrade compounds while others are not? Microbes are able to use organics because of specific enzymes that their genetics encode for. **Enzymes** are biologically derived catalysts. A **catalyst** is something that speeds up the rate of a reaction but is not consumed by the reaction. Microbes produce these enzymes to speed up the destruction of s pecific organic molecules. Each enzyme is specific to one molecule. This concept is not that foreign to everyday life. Our own bodies produce enzymes to help us consume the food we eat. For example, a lactose intolerant person's body does not produce the enzyme necessary to breakdown lactose, a sugar commonly found in dairy. In that same way, some microbes are able to generate enzymes that others are unable to produce.

Working with Microbes—Measuring Growth

When working with microbes, it is important to understand which factors affect growth the most. One way to tell whether or not a microbe enjoys its bioreactor is to see how well it grows in the new environment. Measuring growth with microbes can be a difficult thing to do because of their small size. To accurately measure growth, scientist use a variety of tools to determine cell growth, including direct cell counting and optical density.

The Engineering Design Cycle:



- Ask
    - What is the problem we're trying to solve?
    - What are the limits that our solution needs to follow?
- Research
    - Has someone already created something like this?
    - Who are the experts in this field?
- Imagine
    - Brainstorm a large quantity and variety of ideas before narrowing the options.
- Plan
    - What criteria should we use to narrow down our ideas?
    - Which ideas need to be screened based on the original constraints we identified?
- Create
    - What kind of prototypes can we create? A sketch, scale model, CAD

model, computer simulation, etc

- Test
    - What does our final design need to accomplish? Can we test this with the prototype we made?
    - Run an experiment
    - Create a computer simulation
    - What information are we looking to gain from these tests?
- Improve
    - Based on the results from the testing, what can we improve on our design?
    - Are there certain aspects we found too difficult to create?

Additional Resources

- https://www.youtube.com/watch?v=AmzgtRv0V2I&ab_channel=TeachEngineering
- Nutrient Pollution | US EPA
- pH Scale: Basics - pH | Acids | Bases - PhET Interactive Simulations