Module 6: Agri-Systems Across the Urban-Rural Gradient

Hands-On Activity: Urban/Peri-Urban Light BioLab

Instructions Worksheet for Module 6 HOA B
Grouping: Pairs or small groups (3–4)
Time: 25–40 minutes (initial setup), short daily monitoring for growth and water data over 3 days

Precautions and Hazards

- **Lighting Equipment:** Use caution around LED fixtures. Keep all liquids away from cords, plugs, and power strips. Do not touch bulbs or panels while operating. Allow lights to cool before adjusting height or position.
- **Water & Spills:** Clean up any water spills immediately to prevent slipping hazards. Keep all materials and cords neatly arranged to avoid tripping.
- **Nutrient Solutions:** Hydroponic nutrient mixes may irritate skin or eyes. Wear gloves when handling. Avoid direct contact and wash hands thoroughly after use. Never taste or ingest nutrient solutions.
- **Soil & Compost (Peri-Urban Pots):** Handle soil and compost with gloves when possible. Wash hands after contact. Avoid touching your face while working with soil.
- **Plastic Bags & Transpiration Tests:** Plastic bags are used only for leaf transpiration observations. Never place bags over your face or head.
- **General Conduct:** Handle all seedlings gently to avoid damaging roots or leaves. Maintain clear workspace boundaries and keep all plants in designated growing areas under supervision.

Materials and Equipment

- **Hydroponic system** (e.g., Ahopegarden Indoor Garden) for urban setting set up.
- **Soil + compost pots** for peri-urban setting set up.
- **LED grow lights** (blue, red, blue+red)
- **Lettuce seeds** (or seedlings)
- **Measuring tools** (Ruler (cm); graduated cylinder or measuring cup (mL); soil-moisture meter or "Wet/Dry" probe; light meter or smartphone lux app (optional); **pH test kit** (optional)
- Notebook or printed data sheet; labels or tape for identifying plants

Think Like a Planner

Imagine you're an urban farm planner tasked with designing a climate-smart growing space. Your goal: maximize growth and resilience while minimizing water and waste. In this activity, you'll think like both a planner and a scientist – setting up a mini-experiment to compare growing conditions, then using your results to inform a sustainable design. This module emphasizes systems thinking to evaluate trade-offs in different settings and encourages you to design solutions that improve sustainability across spatial zones.

Context: Climate change is literally increasing the heat. Urban environments face the heat island effect and water scarcity, while peri-urban areas battle shifting seasons and resource constraints. A "climate-smart" growing space adapts to these challenges through efficient water use, resilient crops, and circular practices such as composting and rainwater harvesting.

Challenge: How can we grow food in both a city rooftop and a peri-urban plot so that each is resilient to climate stress? To find out, we'll experiment with two key "design knobs": **light** (simulating climate control with blue vs. red vs. blue+red LEDs) and **growing medium** (hydroponic systems in an urban setting vs. soil + compost pots in a peri-urban setting). You and your team will monitor plant growth and water use under these conditions, then translate your findings into climate-smart design ideas.

Pick Your Path

Pick Your Path: Every planner must make design choices. Here, you get to choose your path by formulating a hypothesis and focus for the experiment:

- **Lighting Focus:** Will blue light or red or mix blue/red light lead to better water-use efficiency? You might suspect one spectrum helps plants use water more efficiently by affecting their transpiration or growth rate.

- **Medium Focus:** Are water needs different between a hydroponic setup and a traditional soil setup? Perhaps you believe the hydroponic "closed loop" system will conserve water compared to soil, which loses some to runoff.

Select a focus question (or combination) that interests your team. For example, *"Do hydroponic lettuce plants under blue LEDs use water more efficiently than soil-grown lettuce under red LEDs?"* This is your path – your mini design inquiry. Write down your hypothesis before you begin. (This is the design thinking stage, where you identify a problem and make a prediction to test.)

Systems Thinking Prompt: Remember that each choice (light, medium, plant type) is part of a larger system. How might your chosen focus affect other parts of the system? (For example, a water-efficient system might need more energy for LED lighting – a trade-off to consider.)

Objective

This investigation explores how **light spectrum** (blue vs. red vs. blue+red) and **growing system** (urban hydroponic vs. peri-urban soil-based) affect short-term plant growth and water-use efficiency (WUE).

Students will monitor lettuce growth under different light treatments (blue, red, and blue+red LEDs) and in two growing systems (hydroponic vs. soil). By the end, you will determine how each environmental factor influences:

- **Water use and runoff**
- **Growth rate** (height and leaf size)
- **Water stress indicators** (turgor, color, soil moisture)

This experiment demonstrates key concepts in urban agriculture and controlled-environment farming, helping you connect plant physiology to sustainability practices.

Group Assignments

- **Group 1:** Lettuce under blue-enriched light
- **Group 2:** Lettuce under red-enriched light
  Group 3: Lettuce under blue+red-enriched light

Each group maintains two growing systems:

- **Hydroponic System** – Represents Urban Controlled Environment (CE)
- **Soil + Compost Pot** – Represents Peri-Urban System

(All groups will collect data in parallel to compare across light and system type.)

Experimental Procedure

Step-by-Step Experiment Guide – Follow these steps to set up your Urban/Peri-Urban Light BioLab:

Now it's time to **prototype** your ideas through a hands-on experiment. Follow these steps to set up your Urban/Peri-Urban Light BioLab:

1. **Setup Teams & Materials:** Form teams and gather materials for both setups: an urban hydroponic system (with water reservoir) and a peri-urban soil pot (filled with soil + compost mix). Each team also needs two young lettuce plants of similar size, and appropriate LED grow light(s) for your assigned spectrum (Group 1 uses blue light, Group 2 uses red light, Group 3 uses a combination of blue+red light). Ensure you have a ruler for measuring plant height, a graduated cup or syringe for watering, and a tray to collect runoff from the soil pot.

2. **Baseline Measurements (Day 0):** Plant your lettuce seedlings – one in the hydroponic system and one in the soil pot. Label your setups clearly (for example, "Blue Light – Hydro Lettuce" and "Blue Light – Soil Lettuce" if your team's focus is blue light, or whichever light your group is assigned). Record initial data in your log:
    - *Plant height* (cm) and *number of leaves* for each plant.
    - *Peri-urban soil pot:* Note down the initial water volume given to the pot (e.g., 500 mL). Note the soil moisture level (if a meter is available) or simply note that you watered it thoroughly at the start.
    - *Hydroponic system:* Note down the initial water volume in the reservoir (e.g., fill to 2000 mL).

3. **Lighting and Placement:** Position the assigned LED light over each setup (e.g., the blue LED over both of Group 1's plants (urban hydroponic system and a peri-urban soil pot), red LED for Group 2 (urban hydroponic system and a peri-urban soil pot), etc.). Keep other conditions equal – use the same room or area to ensure temperature and environment are similar. This controls variables so that **light** and **medium** are the main differences. If possible, place the soil pot in a spot representing "peri-urban" outdoor conditions (for example, near a window or a fan to simulate more airflow), while the hydroponic system can represent an "urban indoor" setup. *(If that's not feasible, it's okay – both setups can sit side by side under their lights, as long as you **imagine** one as "urban" and one as "peri-urban.")*

4. **Monitoring: Every other day (Roughly 3–4 times per week) :** For the next **7-10 days**, maintain and measure your plants:

    - **Watering:** Add a fixed amount of water each day (e.g., 50 mL) to both systems. The hydroponic system is simply topped up to that amount if needed; the soil pot is watered with that amount and allowed to drain into the tray (to simulate runoff in a field).
    - **Runoff Collection:** Measure the water that drained from the soil pot into the tray each day. This water was not retained by the soil. Record the runoff volume. *(The hydroponic setup won't have "runoff," but you might note if any water remains unabsorbed or if you had to add water.)*
    - **Growth Measurements:** Measure plant height and count leaves each day at the same time. Note qualitative observations too: leaf texture or wilting (e.g., *"Is the lettuce droopier under red light? Are the leaf edges curling?"*). If possible, gently feel a leaf in the morning – does one feel crisper (more turgid) and the other softer? Note such differences.
    - **Environment Notes:** Record any other differences in the setups (e.g., *"soil pot feels cooler to touch than the hydroponic system's water,"* or *"blue-light lettuce looks darker green compared to red-light lettuce"*). These observations will help later during design brainstorming.

5. **Final Day (Day 7 to 10, pick what's best) – Harvest Data (Day 3):** At the end of Day 3, take final measurements to quantify total water used and growth:
    - For the **hydroponic system:** Calculate total water consumed = total water added over 3 days **minus** any water remaining in the reservoir at the end.
    - For the **soil pot:** Calculate total water retained = total water added over 3 days **minus** total runoff collected in the tray. (This represents water that stayed in the soil and was available to the plant.)

    Record the final plant height and leaf count for each plant. Then calculate the growth of each plant: *(Final height – initial height).*

    Now you can compute the **water-use efficiency (WUE)** for each setup:

    Calculate growth by subtracting the initial height from the final height.

    Then compute Water-Use Efficiency (WUE) using: $WUE = \frac{Total\ Water\ Used\ (mL)}{Growth\ (cm)}$

    Calculate this for both systems. This gives a measure of how efficiently each system converted water into plant growth. A **lower** WUE value (more mL per cm) means more water was needed per unit of growth (i.e., less efficient), while a **higher** WUE value (fewer mL per cm) means the plant grew more per drop of water (more efficient). If a plant didn't grow or got shorter, note that as well – that's a sign of stress or measurement error.

Throughout the process, **take photos or sketch** your setups. You'll use these in your design justification to illustrate your ideas.

Data Recording: Use the provided data sheet (see **Student Data Collection**) to log all these numbers and observations. Be precise – climate-smart planning relies on good data!

> **Tip:** Work efficiently and communicate within your team. Consider assigning roles (e.g., one person measures while another records data, another waters, another adjusts lights). Collaboration is key – just like running a real sustainable farm where everyone's input counts.

Justify Your Design

Now step back and analyze your results. Pretend you're presenting to a city planning board or a farming co-op, defending a new climate-smart garden design based on your evidence. Use your data to address these prompts as you formulate your "design story":

- **What Worked Best?** – Identify which setup had better water-use efficiency and healthier plant growth. Did the hydroponic (urban) setup use less water per cm of growth, or did the soil (peri-urban) setup perform better? Did blue light boost growth more than red light, or did a combination (blue+red) yield the best results? Identify the "winning" conditions in your experiment and note what "best" means (fastest growth, highest WUE, etc.).
- **Design Recommendation:** Propose a design for a climate-smart growing space using what you learned. For example, "For a dense city rooftop, we recommend a hydroponic system with blue-spectrum LED lighting for lettuce, because our lettuce used water more efficiently under these

conditions." Be specific about your design – mention techniques or features like drip irrigation, rainwater harvesting, shading nets, or vertical farming if your data suggest they'd help. Tie your suggestions to your findings (e.g., if the hydroponic setup was most efficient, perhaps emphasize closed-loop hydroponics; if the soil needed improvements, suggest adding mulch or a soil sponge to retain water).

- **Evidence & Data:** Justify your design by citing your data. Use comparative language to show you've weighed options: for example, "Our hydroponic lettuce under blue light grew 4 cm with 150 mL of water (WUE = 37.5 mL/cm), whereas the soil lettuce under red light grew 2 cm with 150 mL (WUE = 75 mL/cm). This tells us the hydro+blue system was about 2× more water-efficient than the soil+red setup." Explain why that efficiency or performance matters for climate resilience (e.g., saving water during drought, faster growth in limited space, etc.). If one plant wilted less or stayed greener, mention that as evidence of better resilience under those conditions.
- **Leaf Morphology & LED Light:** Include what you noticed about leaf shape, color and structure under each light. Under mostly red light, did leaves look more stretched, thinner, curlier or "leggy"? Under mostly blue light, did they look more compact, thicker, or darker green? Did the red+blue mix give you a "balanced" look between the two? These leaf traits matter: thicker, compact leaves may lose water more slowly and handle stress better, while very thin, elongated leaves may dry out faster. Use your observations about leaf morphology to support or question your design choice for a climate-smart system.
- **Systems Thinking Reflection:** How does your design create a circular, resilient system? Consider nutrient loops (e.g., could food waste be composted to feed the soil?), water recycling (will you capture runoff or rainwater for reuse?), and energy use (if using LED lights or pumps, can renewable energy power them?). A climate-smart design shouldn't solve one problem while worsening another – it finds a balance. For instance, "Using hydroponics recirculates water (closing the loop on water use), and any plant trimmings can be composted to feed our soil-based beds, creating a nutrient loop."
- **Climate Resilience and Scale:** Articulate why your design matters for climate resilience and how it might scale. For example, "This design would make our school garden more resilient to heatwaves (because blue-light indoor systems can be climate-controlled) and droughts (because of water recirculation and rainwater storage). It also demonstrates circular economy principles by reusing organic waste on-site." Envision how it could be expanded or adapted: "If every apartment had a small hydroponic unit for greens, city water demand for produce could drop. Meanwhile, community gardens could focus on crops in soil that thrive with compost – creating a win-win across *our urban–rural gradient."*

As you justify your design, maintain an optimistic and evidence-based tone. You are "growing solutions" as much as plants – show how **innovation meets sustainability**. Use your data to tell a compelling story about why your climate-smart growing space could be a blueprint for the future. 🌱🏙️🌾

Tips for Success

- Handle seedlings gently to avoid damage.
- Keep the distance between lights and plants the same for all setups to be fair.
- Water carefully and measure volumes precisely.
- Always collect all runoff before recording volumes.
- Take measurements at the same time each day for consistency.

Skills You'll Use

- **Experimental design** and hypothesis testing
- **Measuring and recording** biological data

  Evidence-based reasoning (linking observations of stomata/leaf traits and light conditions to results)

- **Systems thinking:** comparing urban vs. peri-urban farming strategies and understanding trade-offs.