Developing Aquaponic Systems Investigation Plan
(TEACHER WORKSHEET)

PREREQUISITES: Students have knowledge of aquaponic systems including photosynthesis, ecosystems, nutrient cycles and creating systems network diagrams (See **Lesson 4** and **"So, What is Aquaponics?"*system network diagram activity*** to get re-familiarized with system network thinking).

Planning the investigation:

1. **Define the Problem:** *(this is the testable question students developed during the aquaponic system science activity in Step 6)*

   Example:
   - *How could we design a system to grow a crop that reduces [how much] water and produces [what amount] of this vegetable to reduce "imports" of this vegetable for the school for [a month]?*

2. **Investigation goal:** *(what do you intend to do?)*

   Examples:

   - "Could we produce enough of a single vegetable for the population of a country for one year? Could we apply these systems to use as part of a larger food production system?"
   - *To see if we can produce enough lettuce in a month to supply 30 grams of lettuce per person in our classroom, to reduce the water use and land use of traditional farming techniques.*

3. **Gather Information:** [To guide students ask questions such as, *What do you need to test? Why? Is it measurable? How? To determine if we were successful at answering the question what do we need to measure to find out?*] Connect the science of aquaponics to understand the reasons for parts of the physical model.) They will need to connect the inputs and outputs to the purpose.

   - How could we grow a vegetable crop in the classroom? (describe) [*Let's start smaller. What do we need to monitor to keep the system balanced? Why? -- How do we grow plants? How will we get the necessary nutrients to the plants?]*

     Example: *Use water, sunlight and soil. We need to know if there is enough nitrogen, oxygen, and other nutrients. [Standard answer is to include soil, so point out to students that in aquaponics, the media (like pebbles) is there for the roots so the plants don't topple over and for nitrifying-bacteria to grow on]. The media needs to allow water to flow through it steadily. Nitrogen needs to be delivered to the plants. Nutrients are replaced regularly because the bacteria produce nitrogen. NItrogen is transported in the water taken up the tubes to the plants. We need a pump to move the water to the plants, from the fish level.*

   - What are the necessary materials (and resources)? (make a list and give a reason for each item or label a diagram with each part and its purpose)

     The media for plants. Bacteria which produce nitrogen. Tubes to transport the water. We need a pump to move the water to the plants, from the fish level. Tubs or containers for the water and the plants. Testing materials. Fish food for the fish to grow. Seeds to grow the plants. Sunlight or a grow-light to provide energy. CO_2 = Carbon source for the plants. Fish "bubbler" or pump system = aeration to provide oxygen for the fish and the bacteria(?)

- What are each of the variables we need to measure? Explain why. (list)

  Nutrients especially nitrogen, are essential for plant growth. Ammonia levels need to be measured, along with pH so that the water is providing a balanced ecosystem (pH is important as a mini-lesson for students -- if the water becomes too acid or too basic, it can harm the fish, and kill the bacteria.) Water is recycled through the system bringing nitrogen from the bacteria, to the plants. The amount that nitrogen and ammonia are (decreasing/ increasing) gives evidence about how actively bacteria are processing the ammonia and reproducing. Plant growth and condition are observed because nitrogen can produce rapid growth. Plant color, such as yellow leaves, mean the pH is out of balance, and wilting plants can mean no enough water is getting to the plants. The fish should be observed too. Fish poisoning produces strange behaviors such as floating nose up, etc.

4. How will you know you have successfully carried out the plan? Use nodes (variables) to explain.

Node: water *-- if we can maintain a system using less water than traditional farming to produce the same crop we have succeeded*

Node: plants *- if we can maintain a system to produce healthy plants, that are harvested and massed equalling our expected output (similar to traditional farming) we have succeeded.*

Node: water (quality *)- if we can maintain a system that is balanced, with pH, nitrogen, ammonia, and oxygen remaining at healthy levels to grow healthy plants and fish, we have succeeded.*

5. Diagram of the solution:

- Draw a design for your aquaponics model (on a separate 11 x 17 sheet). Describe the purpose of each part of the system model (ex. Tube: to bring nitrogen-rich water to plants). Label each of the "nodes" (the input and outputs of the system). Refer to the sample materials (example) on display to design the model.

  (There are many variations depending on the choices offered by the teacher. If time is scarce: use a demonstration model system instead of these steps) This can be a design with a simple pump, tube, plant level, water and fish level. Students should have labeled each part with its role in the system. And shown how many plants the system will produce. Check there is a method for the water, with nitrogen, to get to the plant roots. The diagram should also show that they understand how the nitrogen will get from the fish to the plants. Once complete, share design ideas with another group.

6. Testing the Solution: *Describe the* data that you will collect to answer the question

- **Is the system operating efficiently (in balance)? What is a data collection strategy to determine this?** Write a description of the data collection process and methods you will use to monitor the system. (these are minimum requirements and can be scheduled as suits for the best classroom management scenario)

For 4 weeks : What is measured?

-Measure water quality for the following: pH, nitrogen, ammonia, and oxygen every 2-3 days.
-Add water, and change pH levels to maintain balance every 2-3 days.
-Observe plant and fish health and growth every two days, to check balance in the system

- ***Was enough food grown to meet the challenge?*** **How will results be measured and analyzed to evaluate the design? (***methods and calculations)*

  Water used and grams of crop produced. Measure water over the entire process of growing a crop. Record the amount of water added. Harvest plants from the crown at the base near the "soil level" one at a time, measure the wet mass using a scale. Leave the roots to provide nitrogen and other biomass to the soil. Dry the plants until they have lost all of the moisture (48 hrs approximately) in paper bags. (making sure to mark the bags with the number of plants, and the date of harvest). Mass the plants again for "dry mass" and total the dry masses to come up with the final total production of biomass. (HINT: Here is a link to a method used at ISB see: "Harvesting / biomass measuring techniques"

7. Make a prediction about the outcome for this Design of a Solution:
Example:

This system design can produce ___ lettuce plants, using 5 liters of water in a month. Compared to the water footprint of lettuce this will save, ____ liters of water in a month.)

8. If the predicted outcome result is different: What are 3 possible design changes that could positively affect this outcome? Explain. (*ex. the oxygen level, need for places for bacteria to grow, the number of plants, the type of fish, etc)*

Examples:

- *Oxygen levels were too low for the fish and bacteria, so they acted odd and we did not see nitrogen levels change or our plants did not grow: change the aeration system to a higher rate*
- *Nitrogen levels got too high and changed the pH next time we have to have a better pump system to take the water at a faster rate to the plants, and add more plants to absorb the nitrogen*
- *The plants died because our pump system did not work, so we need to reengineer a new pump system*
- *The ammonia levels were really high, so our bacteria must have not been growing. Restart the bacteria again by changing the water.*
- *Water levels were hard to maintain we used a lot of water because we lost a lot from evaporation, so we will design a cover for the system*

Now you are ready to carry out the plan: Building and investigating an aquaponics model system.