4. OPTIMIZE WATER MOVEMENT IN A GREENHOUSE

It's easy to remember one or two things at a time, but how do you make it easier to remember 15 or more things? You might write a list. For example, you probably don't know the preferred soil moisture, light, humidity, and temperature conditions for some of the more popular houseplants. Even if you did know that information, it would be helpful to have it written down so you can look up the information instead of having to rely on your memory. Computer programs use lists to easily access stored information when needed instead of having to store extra information in memory. Like people, computer programs work more efficiently when more memory is available. In this investigation, you will study how to use water to change greenhouse conditions, and you will write a program that uses lists to determine a good plant choice for Greenhouse conditions.

Goals

- Use temperature and humidity data to optimize Greenhouse program design.

- Use lists or arrays to simplify computational tasks in a program.

Materials and Equipment

- Data collection system
- //control.Node
- Grow Light with included cables and USB power adapter
- Greenhouse Sensor
- Greenhouse Sensor Module with cable and stopper
- Soil moisture probe
- USB Fan

- Power Output Module with cable
- EcoChamber with lid and stoppers
- Small cup or beaker half-filled with tap water
- Plant pot, ~4" x ~4", filled with soil
- Sponge, 2" x 2" square
- Plastic caps from water or soft drink bottles (3)
- Zip-seal plastic bag, quart-size

Safety

Follow these important safety precautions in addition to your regular classroom procedures:

- Don't allow exposed electronic boards to contact a metallic or conductive surface.

- Keep water away from sensor boxes, electrical plugs, and exposed electronic boards.

> *CAUTION:*
>
> - *Don't look directly at the LEDs.*
> - *Don't touch the LEDs.*

Research

List blocks are useful when working with multiple bits of related information. Complete the following to see an example of a list:

1. Connect the //control.Node to your device, choose any template to create a data display, then open the **Blockly Code Tool** 📄.

2. Open the **Code Library** 📄 at the upper-right corner.

3. Change the category from *PASCObot* to *Greenhouse* and open *Model Sunlight*.

4. Right-click or long-press the *to modelSunlight* function block to open the menu as shown. Read the comment bubble ❓ and note 📄 to get an idea of this function's purpose. Study how the code is organized and predict how it works before reading on.

You might have recognized the ordered information pattern as either a table or a three-dimensional **array**. The *growLight* variable **A** is simply a list **B** made up of lists. A list within a list is called a *sub-list*. Individual sub-list values are called *items*. In the *modelSunlight* function, sub-list items are editable inputs that represent time duration in seconds **C**, red LED intensity **D**, and blue LED intensity **E**. The values are editable so you can change the color mix or how long the Grow Light stays on if desired.
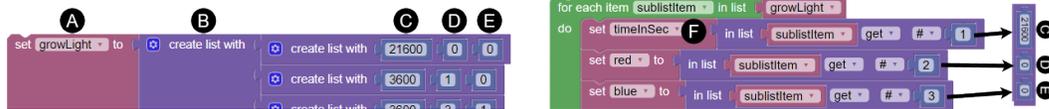
The loop on the right provides instructions for the //control.Node to send to the Grow Light. Let's take a closer look at how the *for each item* loop works. The loop reads one sub-list at a time in order from top to bottom. When the loop gets to the final list, the program will end unless the *for each item* loop is nested inside a repeating loop such as *repeat while true*. Variables **F** are included inside the loop to make a list called *sublistItem* from the values for items **C**, **D**, and **E**. Programmers use the term *index* to identify the position of a list item. In Blockly code, the index for time duration **C** is 1, the index for red intensity **D** is 2, and the index for blue intensity **E** is 3 - that's why you see the numbers 1, 2, and 3 at the end of the *in list* blocks.

Prototype

Part 1: Sensor Setup (Day 1)

1. Make sure the //control.Node is powered off, then plug the Greenhouse Sensor into the Sensor port on the //control.Node **1** as shown in Figure 1.

2. Connect the Power Output Module to port A **2**.

3. Connect the USB Fan to Channel 1 on the Power Output Module **3**.

4. Set up the Sensor Module in the EcoChamber (Greenhouse) lid as shown **4**.

Figure 1. //control.Node, Greenhouse Sensor, and Fan Setup

5. Connect the Soil Moisture Probe to the Greenhouse Sensor. The double arrow on the plug aligns to the back of the sensor as shown **5**. Set the probe aside for now.

6. Connect the Sensor Module to the Greenhouse Sensor. The single arrow on the plug aligns to the back of the sensor **6**.

7. Center the 3 bottle caps at the bottom of the Greenhouse. Set the plant pot with tubing on top of the 3 caps. Adjust the tubing to achieve a U-shape.

8. Line up the side holes with the lid and close the Greenhouse with the USB Fan secured in a side hole as shown.

9. Start a new experiment in SPARKvue.

10. Turn on the //control.Node and connect it to your device. Complete the following in the Sensor Data Configuration screen:

    a. Under Greenhouse Sensor, select ☑ **only** the *Temperature* and *Relative Humidity* measurements.

    b. Disable the //control.Node On-board Sensor measurements by changing the slider from on 🔵 to off ⚪.

    c. Choose the **Digits and Graph** template.

11. Once the data display page opens, set up SPARKvue to automatically stop collecting data after 1 minute:

    a. Go to the **Sampling Options** menu ⊙ and open the **Automatic Stop Condition** menu.

    b. Set **Condition** to *Stop After Duration*; set **Value** to *1*; set **Units** to *min* then choose **OK**.

Part 2: Investigate Humidity and Temperature (Day 1)

1. Start collecting data to observe temperature and humidity over one minute when conditions are stable inside and outside the chamber (control condition). Data collection will stop automatically after 1 minute.

2. Look at the graph legend once data collection stops. Click the run color for Temperature to move the red box to the Temperature data set. Here is an example of a legend with the box around the second data set: ☑ Run 1 ➕➕

3. Open the **Graph Tools** menu �📈. Select the **Coordinates Tool** 🔲 to add a coordinate box to the graph.

4. Move the gray coordinate box to the first Temperature data point. Record the starting temperature in Table 1.

5. Move the coordinate box to the last Temperature data point. Record the ending temperature in Table 1.

6. Calculate temperature change: change = ending temperature - starting temperature; record results in Table 1.

Table 1. Temperature and Relative Humidity Performance Over One Minute under Different Conditions

Condition	Starting Temperature (°C)	Ending Temperature (°C)	Temperature Change (°C)	Starting Relative Humidity (%)	Ending Relative Humidity (%)	Relative Humidity Change (%)
Control						
Fan						
Fan + sponge						
Fan + water						

7. Click the legend run color for the Relative Humidity data to move the red box around it. Use the **Coordinates Tool** to help you enter starting, final, and change in Relative Humidity in Table 1.

8. Click the **Blockly Code Tool** icon 🔷 and write a simple program to run the USB Fan continuously.

9. Toggle the **Blockly Code Tool** icon to return to the data display. Collect the next one-minute run of data to observe how temperature responds to the fan and enter the results in Table 1. The fan should run continuously through data collection. Revise code if necessary.

10. Soak the sponge in tap water and squeeze excess water so it is damp but not dripping. Hold the sponge 1 cm behind the fan as shown in Figure 2.

11. Start collecting data; the fan should be running and the sponge must stay in the same position for the full minute of data collection. When data collection stops, set the sponge aside and record results in Table 1.

Figure 2. Sponge 1 cm from fan

12. Open the Greenhouse. Add just enough tap water to the chamber to completely cover the chamber bottom with water. Replace the lid and fan.

13. Start collecting data. The fan should be running throughout data collection. When data collection stops, record results in Table 1.

14. Optional: Test additional *safe* fan/humidity scenarios and continue Table 1 on another sheet of paper.

15. Return to the **Sampling Options** menu in SPARKvue. In the **Automatic Stop Condition** menu, change **Condition** to *No Condition* and select **OK**.

16. Review the results in Table 1. Share your conclusions for each greenhouse condition in the spaces provided; your conclusions will help you balance soil moisture control with optimal greenhouse air temperature when you are ready to add a plant to your Greenhouse.

    a. What happened to temperature and relative humidity when nothing was changed either inside or outside the Greenhouse (control condition)? Explain the result.

    b. What happened to temperature and relative humidity when the fan blew air into the Greenhouse? Explain the result.

    c. What happened to temperature and relative humidity when water vapor is drawn into the Greenhouse through the fan? Explain the result.

    d. What happened to temperature and relative humidity when standing water was added to the chamber with the fan running? Explain the result.

Part 3: Use Lists in a Program (Day 2)

1. Set a one-hole stopper in an available lid hole.

2. Secure the Grow Light in the stopper. Adjust the Sensor Module and Grow Light until the light sensor is centered as shown in Figure 3.

3. From your data display screen, use the Bluetooth icon 🔵 to open the **Wireless Devices** menu.

4. Select X to disconnect the //control.Node. Leave the menu open.

5. Power off the //control.Node, then plug the Grow Light into Port B.

6. Attach a USB cable to the Grow Light and plug it into its power adapter.

7. Turn on the //control.Node and connect it to your device.

Figure 3. Centered light sensor

8. Write code to accomplish the following:

    a. turn on the Grow Light to the red and blue intensities you wish to use with a real plant on a long-term basis;

    b. create a text output to be used in a **Digits** display to indicate status, such as program in progress;

    c. to factor in added heat from the Grow Light, add a sleep block to allow the light to warm up before moving forward in the program. Use a minimum of one minute for low combined intensities and up to 5 minutes for high combined intensities.

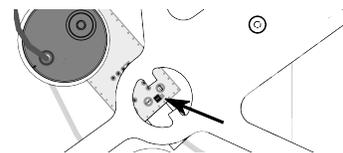9. Add to your code: Create variables for temperature, humidity, and brightness.

10. Add to your code: Use logic blocks to match temperature, humidity, and brightness variables with sensor measurement ranges given in Table 2. An incomplete logic block is shown below Table 2 to help you get started.

Table 2. Criteria for Indoor Temperature, Humidity, and Light Conditions

Measurement	High	Medium	Low
Temperature	Above 75 °F	Between 63 and 75 °F	Below 63 °F
Humidity	Above 55 %	Between 42 and 55%	Below 42 %
Brightness	Above 42 %	Between 28 and 42%	Below 28 %
Your measurements:			

11. Add to your code: Create text outputs for temperature, humidity, and brightness variables (use all lower-case letters) to show their high, medium, or low result. You should now have 4 unique text outputs.

12. Return to your data display in SPARKvue. Add a new page ⊞ and choose the 4-panel layout ▦.

13. Set all panels to **Digits** 1.23 displays.

14. Choose **Select Measurement** in any **Digits** display. In the panel that opens, switch from the **Sensors** tab to the **User-entered** tab.

15. Choose any of the four text outputs you created from the **User-entered Data** measurement list.

16. Assign a different text output to each data display, then test your code. Do not move on to the next step until your code works as expected.

17. Record levels (high, medium, low) for temperature, humidity, and light in the final row of Table 2.

18. Return to the **Blockly Code Tool** and add to your code: Create a practice all-text array as shown below; consider the following:

    a. The first sub-list works like column headings in a table to help keep information organized. The rest of the sub-lists are possible combinations of temperature, humidity, and light measurement results.

    b. Complete the last sub-list. If your results below Table 2 match one of the given combinations, start the last sub-list with MEDIUM to get a new combination. Otherwise, use your results to complete the last sub-list.

Tips:

▪ Right-click or double-tap over any block and choose **duplicate** to copy the block.

▪ Right-click or double-tap on the main list to choose space-saving **inline inputs** for sub-lists.

19. Add the following loop to your code and complete the logic block.

20. Switch to the data display and test the code. Working code will display Status A, B, C, or D in the Status **Digits** display; revise code if necessary. Describe how the *for each item* loop works for this particular code, and suggest a different way to set up the "*get last*" part of the code.

21. Determine the total number of possible temperature, humidity, and brightness combinations. On a separate sheet of paper, refer to Appendix A to create a table that identifies one plant for each possible temperature, humidity, and brightness combination. Add a column for the plant's watering preference. You must use all 10 types of plants, and many plants can be used more than once. There are many correct answers, so it is not likely for any 2 groups to have identical tables.

Test (Day 2)

Redesign your array to accommodate all the information in the plant information table you created; use a 6-panel data display to show all results. Consider the following:

- Add text outputs and rename elements.
- A successful program will identify the ideal plant and its watering needs based on the temperature, humidity, and brightness measurements in your Greenhouse when the Grow Light is on.

Once your program is successful, complete the following:

1. Add dry soil to the pot and compact it until you reach 1 cm from the top.
2. Change one of the **Digits** displays to show %VWC (Loam).
3. Gently push the soil moisture probe into the soil until you reach the bottom of the pot, then compact the soil around the probe.
4. Measure dry soil moisture level and record results in the space below.

5. Pour the soil into the plastic zip-seal bag. Add another ¼ pot of soil to the bag.
6. Add slightly less water than you think is needed to reach the preferred soil moisture level for the identified plant.
7. Seal the bag and mix soil and water thoroughly. Repeat steps 2-3 if needed until the soil reaches the desired moisture level.
8. Add soil to the pot and compact it until the soil level reaches 1 cm from the top.

9. Measure soil moisture as before. On a separate paper:

   a. Record the plant name, its soil moisture requirements, the %VWC (loam) reading for ideally moist soil, and the %VWC (loam) reading for dry soil.

   b. Screenshot and print or sketch your code.

   c. Explain which temperature and/or humidity control strategy might work best to keep Greenhouse conditions ideal for the identified plant (fan; fan with sponge; fan with pooled water; or a strategy of your own design).

10. Save your work in SPARKvue for future reference. Check with your instructor to see if you should save your pot with soil for future use.

Improve (Day 2)

- Use a **Table** display instead of a **Digits** display to show plant identity and watering requirements in a table.

- Create text and audio alerts to indicate when temperature, humidity, brightness, and soil moisture conditions are outside the identified plant's ideal range.

- Use the dry soil moisture data as well as ideal soil moisture data to program the automatic watering system for a range of moisture levels the identified plant can tolerate.

Appendix A: Properties of 10 Small Indoor Plants

Plants that tolerate warm rooms

- Miniature umbrella tree: Requires moderate to high humidity and high light level. Water when top ¼ of soil is dry.

- Kalanchoe: Prefers high humidity and high light level if flowering is desired. Water when top ½ of soil is dry.

- ZZ plant: Hardy indoor plant that thrives under a variety of conditions. Dry soil completely between waterings.

- Aloe vera: Prefers low humidity and high light level. Water when soil is almost completely dry.

- Snake plant: Hardy indoor plant that thrives under a variety of conditions. Water when soil is almost completely dry.

Plants that prefer moderate temperature rooms

- Pothos: Prefers medium to high humidity and a variety of light levels. Dry completely between waterings.

- Assorted culinary herbs: Prefers moderate humidity and high light levels. Keep soil moist.

- ZZ plant: Hardy indoor plant that thrives under a variety of conditions. Dry soil completely between waterings.

- Jade: Prefers low humidity and medium to high light levels. Water when top inch of soil is dry.

- Snake plant: Hardy indoor plant that thrives under a variety of conditions. Water when soil is almost completely dry.

Plants that tolerate cool rooms

- Geranium: Prefers high humidity and light levels if flowering is desired. Water when top ½ inch of soil is dry.

- ZZ plant: Hardy indoor plant that thrives under a variety of conditions. Dry soil completely between waterings.

- English ivy: Prefers medium to high humidity and a variety of light levels. Keep soil moist.

- Jade: Prefers low humidity and medium to high light levels. Water when top inch of soil is dry.

- Snake plant: Hardy indoor plant that thrives under a variety of conditions. Water when soil is almost completely dry.