Name\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Date\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

# Virtual Greenhouse Experimentation

**Purpose**The purpose of this lab is to design and conduct an experiment using a greenhouse simulator and then compose a laboratory report summarizing the research problem, hypothesis, procedures, findings and conclusions.[[1]](#endnote-1)

**Procedure**

**Sequence of Steps**

Write a definition for each of the following terms.

* *Experiment –*
* *Control group* –
* *Control variable –*
* *Dependent variable –*
* *Independent variable –*
* *Random Selection* –
* *Treatment variable* –
* *Validity –*

After a demonstration of the greenhouse simulator by your instructor answer the following questions:

1. In this experiment the manipulation is referred to as the \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.
2. The independent variable in this experiment was \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.
3. Which two variables were controlled?

a)

b)

4. The dependent variable in this experiment was \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.

1. What variable was the treatment variable? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
   1. Describe how the variable was manipulated?
2. Besides the variable described in question #5, what other two variables can be used as treatments in an experiment using the greenhouse simulator? Describe how they can be manipulated.

a)

b)

Now it’s your turn to design and conduct an experiment using the greenhouse simulator. You will need to use the scientific method to do so. Here are the steps:

Define the problem.  
a) Write a research problem that you want to investigate?

Gather information about the problem.  
a) List background information you gather about your research problem?

Suggest possible answers or solutions to your problem.  
a) Write a hypothesis predicting the results of an experiment investigating your research problem.

1. Design an experiment and test your hypothesis.
   1. Record the steps followed in conducting your experiment.
   2. Summarize the data you collected from the experiment in a bar graph.

1. Evaluate the results of the experiment.
   1. Based on the results in the bar graph, what conclusions can be made about your findings? Was your hypothesis plausible?

Now that you have completed your experiment, let’s share what you have learned with other researchers! Using the information you’ve recorded in this lab handout or journal, develop a laboratory report which addresses the following parts:

* 1. Title page – name, class, date, and title of the experiment
  2. Introduction – state the need and justification for the experiment and present background information that influenced the research.
  3. Research problem – the specific question that was under investigation. All the variables influencing the research should be specified.
  4. Research hypothesis – predictions about the effect the treatment would have on the dependent variable.
  5. Procedures – summary of the techniques used in designing, treating, and measuring the variables.
  6. Findings – summary of the data, include any graphs or charts representing the data.
  7. Conclusions – specific statements about the relationships between the variables.
  8. Recommendations – suggestions on how the results of the research should be used or recommendations for further experimentation of the problem.
  9. References – complete listing of all sources used in designing the experiment and preparing the report.

Teacher Resource Guide

# Virtual Greenhouse Experimentation

**Student Learning Objectives:** Upon completion of this lesson, students will be able to:

1. Understand the functions of the greenhouse simulator.
2. Demonstrate the use of the greenhouse simulator.
3. Design and conduct an experiment using the greenhouse simulator.
4. Compose a laboratory report summarizing the research problem, hypothesis, procedures, findings and conclusions.

**List of Resources:**

California Core Agriscience Lesson Plan Library. (2005). *Lesson B1.5:* *Designing and conducting agricultural research*. California Department of Education.

Cooper, E. L. & Burton, L. D. (2004). *Agriscience: Foundations & Applications* (3rd Ed.). Delmar Publishers: Albany, NY

National FFA Organization. *Agriscience handbook: Beginning 2006-2010*. National FFA Organization: Indianapolis, IN

**Equipment and Materials:**

Computer and LCD projector

Computers for students

Internet access

Lab Handout or research journal

**Terms:** (Definitions provided in Appendix I)

Control group

Control variable

Dependent variable

Experiment

Independent variable

Random Selection

Treatment variable

Validity

**Background Information:**

Prior to teaching this lesson, it is suggested that the instructor first present Lesson B1.5 of the California Core Agriscience Lesson Plan Library, entitledDesigning and Conducting Agricultural Research. Lesson B1.5 provides students with the requisite information needed to successfully achieve the objectives of this lesson.

**Interest Approach:**

A local nursery owner has a problem with tomato plants she produces in her greenhouse. The grower plants tomato seeds in January and then sells those plants in April to customers who transplant them into their gardens. Unfortunately, the grower continually finds that the size of her tomato plants is too inconsistent. Some of her plants reach a marketable size by the end of March while others are too small and difficult to sell. The grower needs your assistance in discovering why her tomato plants are not growing at the same rate.

**Summary of Contents and Teaching Strategies**  
  
**Objective 1:** Become familiar with the greenhouse simulator and its functions.

1. Since we cannot go to the actual greenhouse, we are going to use a greenhouse simulator that is available on the Internet. This will allow us to learn about the problems this grower is experiencing and by conducting some experiments we may be able to help solve the grower’s problem.
2. The greenhouse simulator is located at: http://www.kuleuven.be/ucs/env2exp/
   1. Click on the Greenhouse icon to start the simulator
3. The square box in the center of your screen represents the virtual greenhouse.
   1. The greenhouse has two possible lighting schemes:
      1. One light tube – located in the center of the greenhouse from left to right.
      2. Four light bulbs – four light sources, one in each quadrant of the greenhouse.
   2. By default, the one light tube scheme is shown in the greenhouse.
   3. To view the lighting scheme, click on “Options” in the upper left corner of the screen and then select “Visualization Lights”.
   4. To change the lighting scheme, click on “Options” and then “Select Light Model”. Next select either “1 Light Tube” or “4 Light Bulbs” and then click “Apply”.
   5. The greenhouse has two heating sources.
      1. Heaters are located on the left and right sides of the greenhouse.
4. The simulator provides you with twelve trays of tomato plants.
   1. Each tray contains twelve *randomly selected* pots each containing one tomato plant.
   2. The number on each pot indicates the initial size of that tomato plant.
   3. By clicking on the right arrow button, you can view each of the twelve trays of plants.
   4. To select a plant, just click and hold, then drag it into the greenhouse.
      1. The greenhouse has the capacity to hold 144 plants if the pots are placed very close together.
5. By placing plants in different locations in the greenhouse it allows you to manipulate the amount of light and heat that each plant will receive. Let’s see if the amount of light received by the tomato plants has an effect on their growth.

**Objective 2:** Demonstrate the use of the greenhouse simulator.

The instructor should first demonstrate the following procedure while students observe. Following the demonstration, the instructor should repeat these steps leading students through the process on their computers.

1. Select a plant from Tray 1 and drag it into the greenhouse.
2. Place the plant in the center of the greenhouse at the top of the screen.
3. Select another plant and place it directly below the first plant.
4. Repeat Step 3 until all twelve plants are placed in a line from the top to

the bottom of the greenhouse. (Twelve plants will fit if you place them

close together).

1. Once the plants are placed in the greenhouse, determine the length of time the students wish to grow their tomato plants. To set the period of time the plants will grow, click on each of the following arrow boxes and then select the appropriate day and month corresponding to the period of time you desire:
   1. Select the beginDate – day of the month to begin plant growth
   2. Select the beginMonth – month of the year to begin plant growth
   3. Select the endDate – day of the month to end plant growth
   4. Select the endMonth – month of the year to end plant growth
2. Once you have properly located your plants and determined the length of growth time you are ready to grow your plants. To do so, simply click the “Grow” button.
3. After clicking “Grow” the next step is to click the “View Output” button. This will provide you with a data set that represents:
   1. Plant ID number – the order in which you placed the plant in the greenhouse
   2. Initial weight – the biomass weight (grams) of the tomato plant prior to beginning the growth period.
   3. Final weight – the biomass weight (grams) of the tomato plant after the completion of the growth period.
   4. Treatment – indicates the treatment level applied to the tomato plants, in this case no treatment was used other than light so disregard this item for now.
   5. Location of the plant – represented by the X coordinate and Y coordinate (see illustration)
      1. The greenhouse is 8 meters x 8 meters
      2. The X axis extends across the top of the greenhouse from left to right.
      3. The Y axis extends down the left side of the greenhouse from top to bottom.

X axis

0

0

8

8

Y axis

1. In order to analyze the data you will need to copy it and paste it into a spreadsheet program, such as Microsoft Excel.
   1. To do so, highlight all of the text and numbers.
   2. Copy the information – done by right clicking and selecting copy.
   3. Open Excel and paste the data into a new document.
2. The column headings and corresponding data may not align properly. You may need to realign some text.
   1. To do so, highlight the text or numbers you wish to move.
   2. Click on the highlighted information and drag it over to the appropriate cells.
3. To measure the actual amount of growth of each plant it is necessary to subtract the plants initial weight from its final weight.
   1. To do so, create a new column, if one is not already available.
      1. In Excel, this can be done by clicking on “Insert” and “Column”
   2. Label the new column by typing in the first row “Difference”.
   3. Now you can use a formula to calculate the difference between the two weights.
      1. To create a formula in a cell, you must first type an equal sign “=”
      2. Next click on the cell that contains the final weight of the plant in that row.
      3. Then type a minus sign “-“
      4. Next click on the cell that contains the initial weight of the plant.
      5. Your formula should look similar to this: =C2-D2
      6. Once you have done so, press “Enter.
      7. This should produce a value equal to the difference between the plant’s initial and final weight.
   4. Copy this formula and paste it into the other cells below it, which should produce “Difference” values for all the other plants.
4. In order to analyze this data you will need to first summarize the data. By representing the data in a chart or graph it allows you to better draw conclusions from your findings.
   1. Let’s try representing the data graphically, using a bar graph.
      1. To do so, click on “Insert” and “Chart”
      2. When asked to select “Chart Type”, click on either “Column” or “Bar”
      3. Next you are asked to enter the data range.
         1. To do so, highlight all the data in the “Difference” column
         2. Select the button indicating the data is in “Rows”
      4. Click on “Finish”
      5. A bar graph representing the data should appear on your screen, it should be similar to this:
5. The different colored bars represent the growth of each of the twelve plants in the greenhouse.
6. Ask students a series of analysis questions leading them to the conclusion that greater plant growth was observed in the middle of the greenhouse where the light intensity was greatest.
   1. Analysis questions:
      1. Based on this graph what can we conclude about the effect of light on plant growth?
      2. Which plants exhibited the greatest amount of growth?
      3. In which part of the greenhouse was the greatest amount of light?
      4. What is the relationship between the amount of light and plant growth?
7. Based on the answers to these questions, have students form their own conclusions. Then have students share their conclusions with the class.
8. Now that the instructor has demonstrated the use of the greenhouse simulator, ask each student to repeat these steps using their computer.

**Objective 3:** Design and conduct an experiment using the greenhouse simulator.

(**Teacher note**: For additional information pertaining to this topic refer to the Agriscience Handbook, available from the National FFA Organization)

1. An experiment is a scientific investigation in which the researcher manipulates one or more independent variables, controls other relevant variables, and then observes the effect of the manipulations on the dependent variable.
2. The manipulation is referred to as a treatment.
3. Using the previous activity as an example:
   1. Independent variable – light (also referred to as Treatment variable)
   2. Control variables –
      1. Length of time - all plants were grown for an equal amount of time
      2. Heat - all the plants received the same level of heat since they were aligned down the center of the greenhouse.
   3. Dependent variable – growth of the plants
   4. Treatment variable – light, due to the location of the plants the amount of light each received was manipulated. Those in the middle of the greenhouse received the most light and those on the ends received the least amount of light.
4. The greenhouse simulator provides three variables that can be manipulated:
   1. Light – manipulated by the location of the plant in the greenhouse
   2. Heat – also manipulated by the location of the plant
   3. Treatment – various doses of a treatment can be applied to plants in the greenhouse.
      1. The treatment refers to no specific substance. It can be any substance you wish, however for our purposes lets say the treatment is nitrogen fertilizer.

(**Teachers note**: since the treatment has no specific characteristics, by default the effect of the treatment will increase as the dosage level is increased. Suggest to students that they select a treatment that would result in increased plant growth, such as applying nitrogen fertilizer.)

1. We have discussed how to manipulate light and heat sources by changing the location of our plants, but to apply a treatment it requires additional steps.
   1. On the right side of your screen below the plant tray you should see “Treatment”.
   2. By default all of the plants receive Treatment 1, which is set at Dose 0. This means that currently the plants are not receiving any of the treatment.
   3. To apply a treatment to a group of plants you only need to increase the dosage of Treatment 1. As you will see this process will increase the dosage of every plant in the greenhouse.
   4. In order to conduct an experiment, it is necessary to have a control group. This control group would not receive the treatment. This allows the researcher to compare the treatment group with the control group to see if the treatment had an effect on the tomato plants.
      1. To do so, click on the “Add” button next to “Treatment”. This will create “Treatment 2”.
         1. You can then change the dosage of Treatment 2 so that it is greater than that of the plants determined to be in the control group.
         2. For demonstration purposes set Treatment 1 at dosage 0 and set Treatment 2 at 1 or higher.
         3. To apply Treatment 2 to a plant, click and hold on the colored box next to the treatment that indicates the dosage, then drag it over to the plant you want to apply that treatment to and let off your mouse button. If done correctly the circle (plant) should become the color of the treatment you applied to it.
         4. Repeat this process until you have applied all the treatments called for in your experiment.
   5. In order to identify plants that receive different levels of the treatment variables you will want to use the “Group Factors”. These are like marking flags that indicate what group each plant belongs to.
      1. To do so, click on the “Add” button next to “Group Factors”.
      2. “GroupFactor1” should appear in the box
      3. Double click on “GroupFactor1” and another box should open that says “Groups for: Group Factor 1”.
      4. Click on the “Add” button creating “Group 1”
         1. To label a plant in Group 1, click and hold on the colored box next to Group 1, then drag it over to the plant you want to identify and let off your mouse button. If done correctly a portion of the circle (plant) should become the color of the group.
2. Now let’s design an experiment together. Please note these steps since each of you will be asked to design your own experiment following this group activity.
   1. We’ll be following the scientific method:
      1. Let’s first define the problem.
         1. Ask students to suggest possible problems or questions that pertain to the variables included in the greenhouse simulator.

(Example: Does nitrogen fertilizer increase the growth rate of tomato plants?)

* + - 1. Have students record the research problem on notebook paper or in research journals.
    1. Gather information about the problem.
       1. Based on the research question, ask students questions about the problem or have them gather information to provide background information. (Example: Ask students what effect light, heat, and nitrogen fertilizer have on plant growth. If reliable information isn’t provided, have students gather information related to the research question before proceeding.)
       2. Have students record this information in their research journals.
    2. Suggest possible answers or solutions.
       1. As a class, form a hypothesis predicting the results of an experiment.

(Example: Nitrogen fertilizer will have no effect on the tomato plants.)

* + - 1. Have students write their hypothesis in their research journals.
    1. Test the hypothesis
       1. Lead the class discussion in designing an experiment that will test the hypothesis.

[**Teachers note**: To test the effect of a treatment like nitrogen fertilizer, you would need to control for light and heat. This would require that all plants receive similar amounts of light and heat, and one group of plants would receive the treatment and the other would receive no treatment (control group). A more complex design would be to have two treatments, like comparing plants with low light and nitrogen fertilizer to plants with low light and no fertilizer, and plants with high light and nitrogen fertilizer with plants with high light and no fertilizer.]

* + - 1. Have students record the procedure followed in designing and conducting the experiment.
      2. Summarize the data collected in a bar graph. Follow the same procedure as before, copy and paste the data into Excel and create a graph representing the data.

(**Teachers note:** Make sure to sort the data so that the plants from the control and treatment groups are together on the bar graph. See example bar graph)

* + - 1. Have students sketch the bar graph in their research journals.

(**Teachers note:** For more advanced students an alternative method of analysis using a statistical test has been provided in Appendix II at the end of this lesson.)

* + 1. Evaluate the results.
       1. Examine the bar graph.
       2. Ask students to draw conclusions based on the findings in the bar graph.
       3. Have students record their conclusions in their research journals.
       4. Ask students to share their conclusions with the class.
       5. Discuss the conclusions and their validity.

1. Following the scientific method and the same procedures used in the demonstration, ask students to design and conduct their own experiments using the greenhouse simulator.
   1. Follow these steps:
      1. Define the problem
      2. Gather information about the problem.
      3. Suggest possible answers, form a hypothesis
      4. Test hypothesis by designing and conducting an experiment.
      5. Evaluate your results - copy and paste your data into Excel and create a bar graph, then analyze your data.
   2. As in the previous activity have student record each step of the process in their research journal. This information will be used to accomplish Objective 4, which is to compose a laboratory report.

**Objective 4:** Compose a laboratory report summarizing the research problem, hypothesis, procedures, findings and conclusions.

1. Utilizing the information contained in their research journals, ask students to develop laboratory reports which address the following parts:
   1. Title page – name, class, date, and title of the experiment
   2. Introduction – states the need and justification for the experiment and presents background information that influenced the research.
   3. Research problem – the specific question that was under investigation. All the variables influencing the research should be specified.
   4. Research hypothesis – predictions about the effect the treatment would have on the dependent variable.
   5. Procedures – summary of the techniques used in designing, treating, and measuring the variables.
   6. Findings – summary of the data, would include any graphs or charts representing the data.
   7. Conclusions – specific statements about the relationships between the variables.
   8. Recommendations are suggestions on how the results of the research should be used or recommendations for further experimentation of the problem.
   9. References – complete listing of all sources used in designing the experiment and preparing the report.

**Review/Summary** – Once students complete their research reports ask each of them to provide the class with a brief oral summary of their experimental design, findings, and their conclusions.

**Evaluation** – Students will be assessed on their achievement of the learning objectives.

**Appendix I**

Definitions of Terms:

*Control group* – in an experiment, a group of participants who receive no treatment or an alternate treatment.  
*Control variable –* a variable that is held constant so that it will have no effect on the dependent variable.  
*Dependent variable –* a variable that occurred after, and as a result of another variable. In a hypothesized cause-and-effect relationship, the dependent variable is the effect.  
*Experiment –* a research study in which the investigator manipulates one or more independent variables (the treatment) and observes the effect on one or more dependent variables.  
*Independent variable –* a variable that occurred prior in time to and had an influence on the dependent variable. In a hypothesized cause-and-effect relationship, the independent variable is believed to be the cause.|  
*Random Selection* – process of selecting a sample by chance means, so that every member of the population has an equal probability of being selected.

*Treatment variable* – the variable to be manipulated in order to determine its effect on the dependent variable.  
*Validity –* refers to the degree to which researchers conclusions are justifiable and appropriate.

**Appendix II**

Rather than summarizing the data using a bar graph, a statistical test called a paired samples t-test can be used to analyze the data. This procedure tests if the statistical mean (average) of one group is significantly different than the mean of another group. Using this procedure would require that the instructor be familiar with this method of statistical testing and capable of explaining the concept to the students. Microsoft Excel does provide a data analysis tool, which is capable of conducting this test. The following instructions explain how to conduct this test using Excel.

Data Analysis using Excel 2003

1. On the menu bar, click on “Tools” and then select “Add-Ins”
2. A window will open with many available chooses, check the box next to “Analysis ToolPak” and then “OK”
3. Click on “Tools” to access the Analysis ToolPak.

Data Analysis using Excel 2007

1. Click on the MS Office button in the upper left corner of your screen and then in the bottom right corner of the menu click on “Excel Options”.
2. Along the left side of the menu click on “Add-Ins” then at the bottom of the menu box find the “manage:” box.
3. Select “Excel Add-ins” and click on the “Go” button.
4. A small menu box will display available Add-Ins, select the box for “Analysis ToolPak” and allow Excel time to install the new Add-In.
5. Now when you click on the “Data” tab you should see “Data Analysis” on the right.

Using the t-test

1. Just as before - Copy and paste the plant growth data into Excel.
2. Realign the data and the column heading, in a new column create a formula and calculate the difference between the plant’s final and initial weights.
3. New steps – On the menu bar, click on “Tools” and then “Data Analysis”
4. A new window will appear, scroll down the list of available analysis tools until you find “t-test: Paired Two Sample for Means” click on it and then click “OK”
5. Another window will appear, it will ask you to enter two data ranges. Here you need to enter the data from your first group in the box for “Variable 1 Range”. To do so, click on the box, which locates your cursor in the box and then go to your data set and highlight the cells that contain the “Difference” data for your first group only. Once you have done this, the range of cells should appear in the box for “Variable 1 Range”.
6. Next click on the box for Variable 2 Range and follow the same procedure mentioned in item 5.
7. If you choose to test whether there is a significant difference between the means of your two groups you will need to enter a zero (0) in the box next to “Hypothesized Mean Difference”.
8. Once you have completed these steps, click “OK”.
9. Excel will now conduct the t-test and an output will be displayed on a new sheet within your spreadsheet file. This output will display the means for each group and the variance. Towards the bottom you’ll find the t statistic (t Stat) and the p-values. If students predict that the treatment group will exhibit greater growth than the control group then the one tail p-value is the most appropriate statistic to use [P(T<=t) one-tail]. The alpha level is set at .05 by default, so a p-value less than .05 would be considered significant. This would allow the researcher to conclude that two means are significantly different. The one-tail p-value allows the researcher to not only conclude there is a significant difference, but also that the mean of the treatment group is greater than that of the control group.

1. Rocca, Steven (2005).Virtual Greenhouse Experimentation*. California State University, Fresno*. [↑](#endnote-ref-1)