PENNSTATE 1855

eTOXIC
Environmental Toxicology Inquiry Curriculum

Module 1: Everyday Toxicology
Lesson 6: How Do We Interpret and Use Our Data?

Lesson Overview

Summary:

In this lesson, students will collect, analyze, and interpret the data from the experiment they designed and set up during Lesson Two. They will use the data they collect to make a graph of a dose/response curve that will allow them to calculate the median germination failure concentration of NaCl (GFC_{50}, an analogue of LD_{50}) on the seeds they used.

Finally, working in their groups and reporting back in a whole class discussion, students will consider the meaning of these results, critique the experimental system itself, and propose further experiments using this system. These experiments will not be carried out in this module, but could be adopted by ambitious students as out-of-class projects for science fairs, capstone projects, or the like.

Objectives:

By the end of the lesson, students will be able to:

1. draw conclusions based on experimental results.
2. produce dose/response curves from experimental data.
3. estimate median response doses of at least two parameters from dose/response curves.
4. describe the effects of salt on plant germination and growth to instructor satisfaction.
5. evaluate experimental results to instructor satisfaction.
6. describe future potential experiments to instructor satisfaction.

Grades:

9th through 12th

Prepping the Lesson

Instructions:

Materials/Technical Resources:

It is our recommendation that you walk through the teacher and student materials for this lesson to ensure that students will be able to receive the information through the modes of delivery that we intended prior to using the material in the classroom. If you or your school does not have the resources needed, you may need to make some modifications depending on the resources you have available.

The following materials/technical resources will be needed to complete the lesson. We recommend using Option #1 to provide the materials to your students in the manner in which they were intended to be delivered.

Option #1 (Preferred Technology Requirement)
You will need to have access to a computer, the Internet, and a projection device during the entire lesson. Your students will need to have access to computers and the Internet. You and your students will simultaneously step through the module while using their given computers. You may have to make special arrangements for all of your students to have a computer. Be sure you and your students will not be blocked from Google Documents, YouTube, and your selected online collaborative tool. You may be currently using an online collaborative tool but if not, we recommend Facebook groups, Edmodo, or eChalk.

Option #2 (Minimum Technology Requirement)
If you do not have a way for your students to access the Internet individually, then you will need to facilitate their access to the information. You will need access to a computer, the Internet, and a projection device during the entire lesson. You will step through the module as your students watch and complete the presented activities. There may be modifications to the delivery of the materials that you will need to make, depending upon the resources you have available. Be sure you have access to Google Documents, You Tube, and your selected online collaborative tool. You may be currently using an online collaborative tool but if not, we recommend Facebook groups, Edmodo, or eChalk.

Student Homework: Prior to starting this module, it is important to determine which online collaborative tool you and your students will be using. Once you have had an opportunity to review all of the lessons, decide how you will facilitate the homework discussions and submissions using your selected online collaborative tool. Be sure to give your students clear directions and objectives on your expectations of the use of this tool and their participation in their homework activities. We highly encourage you to participate with your students in their homework discussions to enhance the quality of the experience.

Essential Vocabulary: developmental stage, environmental contaminants, four-fold overdose, linear scale, median response concentrations, median response dose, supplement pills, NaCl dilutions, synergistic pollutant effects
(See Lesson 1, 2, 3, 4, and 5 for additional vocabulary words.)

Lesson Time and Supply List:

This document will provide you with information on prep time needed, a list of supplies, and total lesson time for this particular lesson. See appendix for the Lesson Time and Supply List document.

Student Notebook:

Laboratory notebooks are arguably the most useful tool at an experimenter's bench. Remind students of the critical importance of recording all experimental observations, and especially recording all experimental conditions (e.g., the type of chemical treatment, the range of concentrations, number and species of experimental subjects, etc.) when starting an experiment so that they can maintain comprehensive, unambiguous control over those variables when they follow up with subsequent experiments.

Implementing the Lesson

Instructions:

> ***Teacher Tip:*** *Remember that this experimental system necessitates the subsitution of concentration for dose. Thus when we refer to dose/response curves in this context, we are technically referring to conentration/response curves. Since students will be measuring arbitrary biological responses, we refer to median response dose as a general case of, e.g., median lethal dose or median effective dose. Likewise, we use the terms median response dose and median response concentration interchangeably.*
>
> *Finally, failure to germinate serves as a proxy for lethality, despite being a very different endpoint.*

1. Guided Discussion (5 Minutes)

> ***Teacher Tip:*** *Students' answers to the second homework question will motivate a whole class discussion that follows their collecting and processing their experimental data.*

<u>Catechin Effects by Time Course: Small Doses vs. Supplement</u>
Review the answers to the first homework question that was posted to the online collaborative tool.

Students ought to have had the insight that a four-fold overdose of the supplement pills can lead to blood levels of green tea catechins that are toxic to the liver for a significant portion of the day, while blood levels of those molecules from tea itself would be well below the toxic threshold for realistic amounts of tea intake. Thus, one difference between supplements and "natural" sources (e.g., bulk food sources) is that toxic doses can be much easier to receive by accident from supplements. *(See the online verison of Lesson Six for a video with example answers.)*

2. Group Activity (10 Minutes)

<u>Collecting Data and Observations</u>
During lesson 2, students thought carefully about their experimental designs and produced an Observation Table for their notebooks into which they could efficiently collect all the data needed to fulfill their experimental objectives.

Recall that students should be measuring the number of seeds that fail to germinate at each concentration, along with at least one other variable (e.g., length of sprouts).

Students should collect their data before proceeding to analyze and interpret them.

Students should not overlook the critical importance of collecting all of their observations into their notebooks, including, but not limited to, measurements that they make with their Observation Tables.

3. Group Activity (20 Minutes)

Data Analysis and Interpretation

Students should have thought during lesson 2, at least implicitly, about what they would do with their data, in particular about how they would use the data to construct dose/response curves, and in turn how they would use dose/response curves to calculate or estimate, for example, a median germination failure concentration, or GFC_{50}.

For each parameter that students measure, they will produce a dose/response curve and calculate or estimate the median concentration for that response. Whatever else they decided to measure, each group will make a curve that allows them to determine the median germination failure concentration, or GFC_{50}.

Note in particular that if students measure the **number of seeds that germinate**, they will have to take the extra step of converting those data into the **number of seeds that fail to germinate**. This manipulation is trivial:

number that fail to germinate	**=**	**total number of seeds**	**-**	**number of seeds that germinate**

Students should decide how they will convert their raw data into a dose/response curve of the form in which they have seen so many examples in this module:

- descriptive title
- axes labeled
- X axis is dose (or concentration, for these experiments)
- Y axis is percent of subjects with a particular response (e.g., percent failing to germinate) from zero to 100%
- median response dose labeled

Students can use whatever means they are comfortable with to produce these graphs. Spreadsheet software of any type will do the job, as would graph paper and pencil. (We recommend a platform like Google Spreadsheets that allows students to easily share their results with one another.)

Finally, students can calculate median response concentrations directly from a spreadsheet's formula for estimate of fit, or merely make a visual estimation by interpolation directly from their graphs. Mistakenly, using a linear scale (rather than logarithmic) will distort the curve somewhat, but not unrecognizably. However, it will make interpolating GFC_{50} more difficult.

Again, students should recognize the critical importance of **collecting all of their analyses and conclusions into their notebooks,** including, but not limited to, their dose/response curves, their estimates of median response dose/concentration, and the like.

Active research scientists cultivate the habit of asking the following sorts of questions every time they finish an experiment. The next three sections of this lesson will use these questions to guide group discussion in order to critique students' experiments:

1. What were the **results of this experiment**?
   What data did you collect? What observations did you make? What analyses did you perform? What conclusions did you draw?

2. What is the **next experiment**?
   What subsequent experiments would you carry out with this experimental system, if you had the time and materials?

3. How could you **extend or improve the experimental system**?
   What weaknesses of the experimental setup (and design) did your work reveal? What questions do you want to investigate that this experimental system cannot help you answer? What refinements can you propose that would overcome these shortcomings?

4. Guided Discussion (10 Minutes)

What Were the Results of the Experiment?

Students have now entered into their notebooks all of their observations and their analysis and interpretation of results, including producing dose/response curves for each of the biological responses they observed and estimating median response concentrations for those responses. They will next share their conclusions with the whole class.

Have students share their:

1. observations
2. analyses
3. conclusions

The following questions are likely to come up during this discussion, and might serve as a useful guide:

- How well do groups' measured median germination failure concentration or GFC_{50} agree with one another? How well did the rest of the graphs agree?

- What other parameters did each group measure?

- For groups that measured the same responses, did their observations agree?

- For groups that measured different responses, what extra insights, if any, into the effect of salt on plants can be drawn from them?

- Is there **anything about your design that you would change** if you did the experiment again?

One way to propel the discussion to the higher levels of the next two discussion questions—from a consideration of the results of these particular experiments to **a discussion of the appropriate next experiment** and a higher-order **examination of the experimental system itself**—might be with prompts such as the following:

- What do these results **mean**?
- **What other questions could we answer** with this experimental system?
- What other work would we have to do in order to **connect these results with the "real world"?** With actual crops? With actual environmental contaminants?

5. Guided Discussion (10 Minutes)

What is the Next Experiment?

In most cases (including this one), experiments in laboratory course classroom settings are necessarily self-contained. In contrast, in research settings, each experiment is just one step in an overarching research program occupying the time and expertise of a whole team of scientists. Even more importantly, **the goals of the research program are not fixed, but depend directly on the results generated by experiments.** Thus the process of actual research is recursive and explicitly, deliberately, self-referential.

These insights are difficult to demonstrate in the context of a laboratory course, and are almost always outside of the direct experience of students. However, one way to provide students with a glimpse into this process is to exploit the intellectual momentum students obtain at key times, such as now when they have just completed their interpretation of the results of an experiment of their own design.

In fact, the typical behavior through which working scientists experience this process is that they habitually ask themselves, just as soon as they draw conclusions from the results of one experiment, **"What is the next experiment?"**

Often the "next experiment" is two or three or five next experiments that might take place in parallel or in sequence. In some cases, the next experiment(s) will be variations on the previous one, each perhaps varying one experimental parameter or condition. In other cases, the next experiment(s) might call for an entirely different experimental system.

Students should consider in their groups, and then report back to the whole class, their answers to the question **"What is the next experiment?"**

Possible answers to the question are likely to overlap with those listed in the following section.

6. Group Activity (10 Minutes)

How Could You Extend or Improve the Experimental System?
Review the experimental system briefly; students are now intimately familiar with it: petri dishes, NaCl dilutions, one type of garden seed, and a 3-7-day incubation period.

During lesson 2, when students designed their experiments, they discussed the shortcomings (and advantages) of this system. Do they have any further criticisms based on their experience with it? What suggestions do they have for changing or extending this experimental system, and for what goals?

Obvious answers will be similar to the following:

- *grow seeds in soil (in a laboratory) instead of dishes with paper towels*
- *grow seeds in the field*
- *test the effects of other kinds of salt (including road salt preparations of chemical composition other than NaCl, like KCl or proprietary formulas)*

- *test the effects of other kinds of substances (including other sorts of pollutant runoff)*
- *test different types of seeds*
- *compare weeds to crop plants*
- *examine effects over longer time periods*

More subtle or sophisticated answers might include:

- ***What about synergistic pollutant effects?*** *How is the effect of salt on germination changed in the presence of other contaminants? Are there concentrations of NaCl and other substances that alone show no effect on germination, but together show measurable effect? What common substances would you decide to test? Even apparently harmless substances might have an effect in combination!*

- ***How important is the developmental stage?*** *Are seedlings and adult plants more or less sensitive to salt (or other contaminants) than seeds? Does the effect change if you start salt exposure after a certain stage versus continual exposure from a seed?*

- ***What about yield?*** *Do you observe a lower mass—of the whole plant, or of harvested parts like roots or fruit—at levels of salt exposure at which plants germinate and otherwise appear healthy?*

- ***When is failure to germinate not the same as lethality?*** *If you limit salt exposure to, say, 7 days, then subsequently rinse the sprouts and grow them in distilled water, do they recover? Do they recover as fully as those that were not exposed to salt? How long must they be exposed before the damage is permanent (and by what criteria)? This line of investigation explores the gray area between the terms "acute" and "chronic."*

Appendix

Prep Time, Supply List, and Total Lesson Time

Prep Time:

We recommend 30-45 minutes depending on your expertise level with the content. Each module will vary depending on your previous experience with the content and technology.

Materials:

Each student will need
- their laboratory notebook and observation table along with access to their group's petri dishes.

Each group will need
- a ruler
- a calculator
- forceps (to handle seeds and sprouts)
- magnifying glass

You will need
- to identify two or three student examples from responses to the first homework question located in your online collaborative tool.
- to provide students with access to their petri dishes so they are able to conduct their observations.
- to provide support to the student groups as they work on analyzing their observation data.

Total Lesson Time:

Lesson Activity	Amount of Time in Class
Guided Discussion: Catechin Effects by Time Course: Small Doses vs. Supplement	5 Minutes
Group Activity: Collecting Data and Observations	10 Minutes
Group Activity: Data Analysis and Interpretation	20 Minutes
Guided Discussion: What Were the Results of the Experiment?	10 Minutes
Guided Discussion: What is the Next Experiment?	10 Minutes
Group Activity: How Could You Extend or Improve the Experimental System	10 Mintues
Total Time	**65 Minutes**