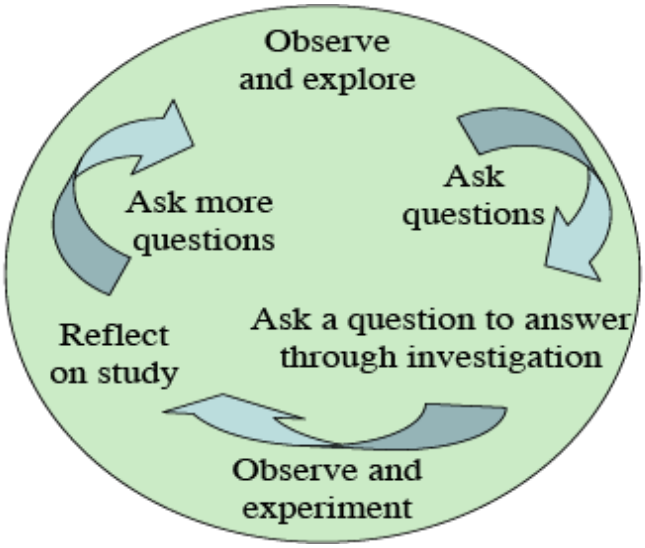
BOTANICAL SOCIETY OF AMERICA

THE WONDER OF SEEDS—SPROUT INVESTIGATION

Student Research Guide

Contents

Inquiry as a Cycle, Science as a Process



The Inquiry Cycle Never Ends.

One good question leads to many more!

Inquiry begins with looking carefully around you and wondering about what you see. Once you see something interesting, you naturally want to find out more about it. At this point in the cycle, all questions are good questions. The more you wonder about something, the better.

Scientific inquiry is a special case of inquiry. Scientific inquiry relies on understanding basic concepts to reach a testable research question. Through the initial engage and explore activities, you will begin to build this knowledge base. Conduct your own background research to further develop it.

Selecting a question that can be answered through investigation gets easier with experience. The why questions are really difficult. The how, what, when, and where kinds of questions are more answerable (testable). "Why are there so many kinds of plants?" We might never know the full answer to that fascinating question. But we can get a handle on questions like "Where is plant diversity highest" and "What environmental factors influence plant diversity" and "How do invasive plants impact native plant diversity."

Once you have selected a testable question, then you need to decide the best research method to test it. This is the stage in the process where you develop your research plan and experimental design. Observing nature carefully and taking notes about what you see can answer some questions. Other questions are better answered by experimenting--manipulating conditions. The condition that is manipulated by the investigator is the independent variable of the study (e.g., light conditions). The factor that is being measured by the investigator is the dependent variable (e.g., plant growth).

Creativity is highly valued in the scientific community. Big breakthroughs often come when a researcher looks at a problem in a new way, or tries an innovative method to answer a question. Equally, if not more important, is being careful and systematic in thinking, planning, and measuring. If you are interested in testing the effect of light on plant growth, it is important that other conditions like temperature and moisture are the same for all samples in your experiment.

The data you collect serves as the “evidence” that you must interpret and use as a basis for your conclusions. Consider the results carefully. Reflect on every part of the investigation. Then share your ideas with others, get some feedback from them, and review the work of your peers. You can learn a lot by comparing your work and talking about it.

Science does not occur in a vacuum. Scientists often work in teams and collaborate with other research labs to answer the same question, or to connect their experiments to others to answer bigger questions.

How To Grow and Track Sprouts

Materials

- seeds to sprout
- growth chamber (1-liter plastic bottle, with top portion cut off, for each student)
- box large enough to hold growth chamber, with small window cut out of top (for half of the students)
- 1 piece of screen or netting
- rubber band or ring for growth chamber
- journal for documenting investigation
- data sheet for recording growth
- Internet access for uploading journal, comments, and data

You will be each responsible for sprouting seeds in a growth chamber as part of a class experiment. Some of you will keep your growth chambers on a windowsill. Others will keep your growth chambers in boxes that have a small window at the top. As a class, you will be conducting an experiment to explore the role of light on plant growth.

1. Make a note of the species you will be growing on a Sprout Tracking Sheet. Note the light condition you are testing, and your name and your Team's name.
2. Take a close look at the seeds and describe them. Look at your classmates' seeds and make notes about their size, coloring, and shape.
3. Count the number of seeds you have and enter that number on the Sprout Tracking Sheet.

   [NOTE: Depending on the size of your growth chamber and seeds, you will use anywhere from 1/4 teaspoon of seeds to 1 tablespoon of seeds. A good rule of thumb is use enough to cover the bottom of the container with one layer of seeds.]
4. Add the seeds to your growth chamber. Label your growth chamber with your name and the start date of the experiment.
5. When you get back to your home, pour enough water in the growth chamber so that the seeds are all under water and have at least 2-3 cm more over them.
6. Put the growth chamber either on a windowsill or in a box.
7. In the morning, empty the water, and make a note of any changes you see. This step allows the seed to absorb (imbibe) water and starts the germination process. Make sure that you remove excess water droplets. Wet sprouts will rot instead of germinating. It is helpful to let them drain upside down for a minute or so. Be gentle as you swirl the germinating seeds to rinse them.
8. Each morning for the next 13 days, rinse the sprouts once a day. Gently run water into the growth chamber through the netting and gently swish the seeds in the water. Dump the water out and gently shake the growth chamber to remove excess water droplets. It is

helpful to let them drain upside down for a minute or so. Record any changes you observe. Return the growth chamber to its location once you have rinsed and observed the seeds.

9. Once the seeds have begun to sprout, measure the length of one sprout (in cm) every day. It is likely your sprouts will not grow perfectly straight----Can you think of a good way to measures something that is not straight?

Over the course of two weeks, closely observe the growth of the seedlings and document our observations daily on your data sheet. Be sure to make note of the first day the root is visible, the first day the shoot is visible, and the first day that true leaves appear.

On day 14, graph the sprout growth data you have collected in Excel (See the help sheet at the end of this document).

Sample Data Sheet
(use this sample or create your own)

Sprout Tracking Form for: _____ Member of Team _____

Sprout name _____ Number of seeds _____

Seed description:

Description of experimental conditions:

Date	Rinsed	Length (cm)	Seed swells, seed coat cracks, roots, shoots, leaves visible?	Other Observations

Happy sprout farming!

Step-by-Step Research Guide

1. Keep a record of your team's investigation in your JOURNAL.
This guide will help you think through your research problem. To answer each of the questions use careful reasoning and systematic thinking! Remember to use any observations or experiences from everyday life, as well as scientific facts and evidence to help you consider your ideas. Write in the journal any time you want to bounce around new thoughts or ideas. Don't be bashful! Every scientist has been wrong many, many times in their career! The challenge is finding out how things really work!

Your journal (or laboratory notebook) is the long-term record of your work. Record in it everything someone else would need to know in order to re-create your experiment. Keeping careful records of ideas, research plans, and research results is very important.

In your first journal entry, record your school and team name. List the first names of the team members. Be sure you include the date for each new entry in your journal or data sheet.

[Note that each team has a blank MS Word journal on their team's web page, a sample is given below. Click on the Our Journal link to access this sheet, save this sheet to your computer, and begin using it to record your investigation. Each team has a blank MS Excel sheet on their team's page. Click on the Our Data link to access this sheet and set up a data sheet that matches your team's research question. See the WebGuide for further details on saving and uploading it.]

Example Journal Page with first entry
County School, Team 1—Jessie, Tryna, Ulrich, Reilly

Date

2. Explore the basic research problem you will be investigating.
The research problem is the general topic you will be investigating. In this case, you are exploring seed germination and seedling growth. Before you begin to refine your research, take a close look at the different types of seeds and ask yourself some general questions.

How do they differ in appearance (size, color and shape, etc.)? If you cut open a seed, can you identify the parts?

Which species do you think will germinate first? Why do you think so?

Grow longest? Why do you think so?

Have the highest sustained growth rate? Why do you think so?

3. Research your problem, your plants, and your experiment.
Research is not just an experiment. Scientists use books, periodicals (which they call "journals"), and research reports from other scientists to study their problem. This process is called background research.

Use the "How to Grow Sprouts" sheet to help you understand how sprouts are grown. You can also look at the links under "Resources" to gather more background information. List the important facts or ideas you know or think you know about sprout growth before starting your research.

Here are some starting questions to start you thinking about sprouts.
a. What are monocots and dicots? Is your sprout a monocot or dicot?

b. Why do we need to rinse the sprouts daily?

c. Is measuring only one sprout a day a good way to collect accurate data? Why or why not?

As you do your background research, write down what you discovered in your research. These are notes and not a final draft, so lists, incomplete sentences, etc. are fine. Record your background research in your journal. Note who contributed each piece of information or idea.

Example Journal Page with background research
County School, Team 1

Date

Our Background Research

What we know or think we know about sprouts: (You may not know where some of these facts or ideas come from. That's okay.)

Fact 1 (sprout sheet) - Jenny
Fact 2 (my experience or observation) - Marcus
Fact 3 - Jamsheed

What we discovered from reading: (Make sure to write down the link or sheet title from which you got each piece of information and the team member who contributed the item.)

Fact 1 (botany book title and author, page number) – Jamsheed and Ayesha
Fact 2 (web link URL, title) - Marcus
Fact 3 (etc) - everybody

4. Identify questions that interest you.
Based on your class discussion and background research, what do you WANT to know about sprout growth? Write them down in your journal. Note who contributed the question.

Example Journal Page with Research questions that interest your team
County School, Team 1

Date

Question 1: Will the smaller seeds germinate faster than the larger ones? – Jamsheed
Question 2: YYYYYYY – Ayesha

Hypothesis 1: Temperature will affect the germination rate of seeds – Tonya

5. Work as a team to state the research question you will test as a team and describe the research plan to test it.

Things to consider in developing your research plan:

- What kinds of data will you be collecting?
- What tools and methods will you use to collect your data?
- What will your data look like?
- In what format will you collect your data (table, chart, etc.)?
- Also remember that description (qualitative data) is just as valid numerical data. What kinds of observations can you make and record in your experiment?

IMPORTANT QUESTION: As you plan your experiment, keep asking yourself, "DOES YOUR EXPERIMENT ADDRESS YOUR RESEARCH QUESTION?" If you get off-track, just go back and tweak your experiment to focus back on the question.

Example Journal Page with Research question or hypothesis and research plan
County School, Team 1

Date

Our testable research questions.
Do seeds germinate faster under light or dark conditions?
Do sprouts grow at the same rates in light and in dark?

Our hypothesis (this is possible explanation for what you observe/or know from reading) is…

Our prediction (this is what you expect to see) is…

Our research plan.
The variables we will test… (what will be manipulated? What held constant?)
The things we will measure &/or count…
The things we will observe..
The way we will record the data

6. Start your experiment and record your data and upload your data regularly (say twice a week) on your team's page on the BSA's website http://www.botany.org/scientific_inquiry/. Gather the materials, tools and instruments for your experiment. Have your data collection tables, charts, etc ready. Begin recording your data.

IMPORTANT! Record anything you might observe that you think might influence this data point and any human error that might have occurred to make the point less reliable.

IMPORTANT! You might notice something toward the beginning of your experiment that might be an important factor in figuring out what your experimental data mean. Sometimes you can modify your experimental design even after you start your experiment to add this new observation. For instance, you might notice something about seed size or that only half the seeds actually sprout. If you don't consider these types of data when you design your experiment, note them in your report and ask your instructor if you can add the data some way to your results. This kind of careful observation and notetaking during an experiment can be a good source of new experiments and great discoveries later on!

7. Summarize and analyze your data.
The data you have recorded in your data sheet is what scientists call "raw data". The data must be put into a format in which scientists can easily compare data and visualize data. This usually means a graph of some kind.

8. Make meaning or sense of your data. Explain it.
Report a summary of your data in your journal. Stop and think about your results. Feel free to find out what other teams have discovered and try to fit the relevant experiments from other teams into your picture of how seed sprouting works.

Give an explanation of the data in your online journal. Make sure to use your evidence (experimental findings) to backup each point of your explanation. Explain your thinking about how you arrived at this explanation. If you use evidence from another team's experiments to further extend or support your explanation, make sure to cite them in your report.

Example Journal Page with Research results
County School, Team 1

Date

Summary of our results.

How many days until the first seed germinated?

How many days until 95% of the seeds germinated?

How many seeds had not germinated by the 14th day?

What percentage of seeds germinated?

How many days until it produced a root?

How many days until it produced its first shoot?

How many days until it produced a first true leaf/blade?

What is the length of the largest leaf/blade on day 14?

Explanation of our results.

Do you accept or reject your hypothesis regarding the species that will germinate first?

Do you accept or reject your hypothesis regarding the species that will grow the longest?

Do you accept or reject your hypothesis regarding sprout with the highest sustained growth rate (equal amounts of growth over all days, rather than one big growth spurt)?

9. Prepare a scientific poster about your research and post it to the website and to your class

Scientists do this in the real world. Scientists sometimes perform almost identical experiments. In fact, this is routine. It helps to confirm and solidify the evidence base for determining how things work.

10. Give online feedback to your fellow research teams about their posters.

Useful input might be how your findings might relate to theirs, if at all, and what you might have been thinking about the same problem or question. Also, in critiquing, use the definition of inquiry to help guide your comments. Did the team make careful observations? Did their experimental design address their research questions? Did they collect and analyze their data adequately? Did their explanations make sense with respect to their data? Did they plan and reason carefully?

11. Compare your data to other teams in the class and reflect on your experience and derive new questions from your experiments.

Consider what you have learned from germinating and growing sprouts. Enter your new questions and some of the questions that resulting from the class discussion in your online journal. Remember to give your explanation for how you and/or the class came to that question.

Example Journal Page with Reflections on Sprout Farming
County School, Team 1

Date

Things we have learned about plant growth and development through investigation.
Here are some possible items to consider:

How does monocot development differ from that of dicots? (Development refers to how sprouts grow, what order do structures develop in? What structures do you see as it grows?) Do your sprout observations support these definitions or not?

What have you learned about caring for plants as a result of this project?

Based on the class data, what factors do you think most influence a seed's ability to germinate and grow into a plant? Why do you think so?

New questions we have.

Any additional observations/comments on this project?

Microsoft Excel: Entering Data and Creating Graphs

Entering Data on a Spreadsheet

When you open Excel a spreadsheet will appear. This is where you will enter your data, which will later be made into a graph.

- Column A will become your X axis. **Number each box in column A from 1-14** to represent days. To number quickly **type 1 in box A1** then **type =A1+1 in the *fx* box** at the top of the screen, then **highlight boxes 1-14** and the numbers will appear.
- Column B will become your Y axis. **Enter your data** by clicking on the boxes in column B one at a time and typing in your sprout length in cm for each day beginning with day 1 in box B1 and so on down the column.

Making a Graph

- Once all your data is entered on the spreadsheet, **highlight both columns A and B** by clicking and dragging across all of the boxes you entered, then **click the graph icon button** in the menu at the top of the screen.
- Select **Line Graph** from the Chart Type menu.
- **Select the second option down on the left**, "Line with markers displayed at each data value", from the Chart Sub-Type menu**. Double click it.** A preview of your graph will appear.
- Click on the **Series tab** at the top of the preview graph, highlight **Series 1** and hit the **Remove** button below it. This will make the blue line disappear.
- Click **NEXT.**
- Now it will ask you to title your axis. **Under X Axis type "Day", Under Y Axis type "Length (cm)"** in the boxes to the left of the graph. **Title the chart with the name of your sprout.**
- Click **NEXT**
- Select **As New Sheet**. Now your finished graph will appear.
- **SAVE** to your hard drive and to a disc to bring to class.

Inquiry guide by Beverly Brown, Ph.D., Nazareth College, Claire Hemingway, Ph.D., The Botanical Society of America, Sandy Honda, Ph.D., Univ. of Maryland, César Larriva, Ph.D., California State Polytechnic Univ.-Pomona, and Peggy Skinner, The Bush School, Seattle, WA.