BOTANICAL SOCIETY OF AMERICA

SPROUT INVESTIGATION
Student Research Guide

Contents

How To Grow Edible Sprouts

1. Place seeds in your sprout growth chamber.
2. Fill chamber with enough water to cover seeds with 2–3 cm of water.
3. Put sprout chamber in a dark, warm place overnight. (A closet or cabinet will work.)
4. In the morning, empty water from sprout chamber. Rinse sprouts several times with clean water. Drain upside down for a minute or two. Remove excess water droplets to prevent sprouts from rotting.

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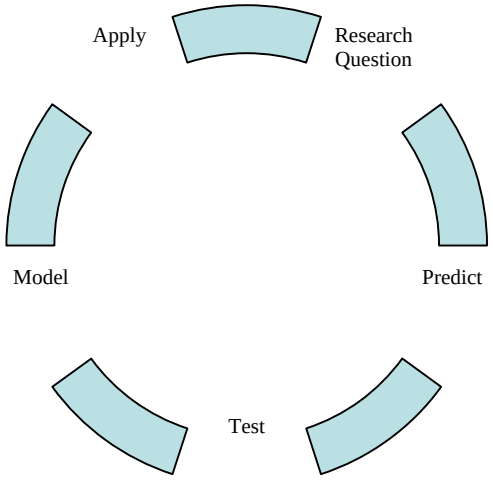
Inquiry Cycle



The Inquiry Process Never Ends.

One good question leads to many more!

- Model of Scientific Inquiry Process
  You will use these items to assess your own learning and your that of your fellow classmates:

  - Understanding the Main Ideas—How well did you reflect on the current body of scientific evidence to formulate your research questions? What is your working model of seed sprouting?

  - Understanding the Inquiry Process—How does your working model of seed sprouting connect with your research questions? Did you think carefully and plan your experiments well? Did you interpret data using appropriate math tools? Did you display your data in a manner that could be easily understood? Did you describe how you used your evidence to modify your working model for "seed sprouting"?

  - Being Inventive—This is a highly valued quality in the scientific community. By using creative methodology, approaches and analytical tools and making creative connections to other fields, scientists make great advances.

  - Being Systematic—Doing science is about being systematic in examining and manipulating variables in experimental design. Being thoughtful and careful in thinking and planning are equally, if not more, important characteristics of the scientific process.

- Reasoning Carefully—Critical thinking and taking the evidence base and all possibilities into consideration are hallmarks of good science. Students must learn to reflect on their own thinking, while debating and incorporating other student's ideas into the base of evidence.

- Using the Tools of Research—What are the key tools of research that students can use in this investigation? Help them identify what some of them might be. Math is one of the key tools in science. Using math correctly and creatively makes sound science.

- Teamwork—Scientists routinely work as teams and teams communicate with each other go build the information base and models. Scientists often collaborate across fields of expertise to broaden the research questions they can ask and to connect their research questions to the bigger questions in biology and science in general.

- Communicating Well—Science does not occur in a vacuum. In order to refine and expand conceptual models within and across disciplines, scientists communicate their findings through publication, presentations to peers, and review of peer work. This process also allows for peer review, a checks-and-balances process by which scientists check and question each other's work to make certain that integrity is maintained.

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Step-by-Step Research Journal Guide

1. Record all of the work in this guide in your team's ONLINE JOURNAL.
This guide will help you think through your research problem. Answer each of the questions thoughtfully and carefully. Remember to use any observations or experiences from everyday life, as well as scientific facts and evidence to help you consider your ideas. We also want you to write in the journal any time you feel like you want to bounce around new thoughts or ideas. In the real world of scientific research, every idea is considered. So don't be bashful! Every scientist has been wrong many, many times in their career! The challenge is finding out how things really work!

2. Identify the basic research problem you will be investigating.
In other words, what is the basic research problem you are investigating? You do not have to have a specific research question yet. The research problem is the very general topic you will be investigating.

3. Research your problem.
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 Edible 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 knew or thought you new about sprout growth before you started your research. Then as you do your research, write down what you discovered in your research. These are notes and not a final draft, so lists, incomplete sentences, etc. are fine.

Example: Background research page

Background Research

What I know or think I know about sprouts: (You may not know where some of these facts or ideas come from. That's okay.) Write down who on your team contributed the idea.

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

What I 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.)

Example: Facts and ideas from reading

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

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

Example: Questions we have about sprout growth

Question 1: XXXXXX? – Chris
Question 2: YYYYYYY? – JoAnn

5. Work as a team to identify one team question that you can test experimentally.
Hint: You may have to break down your questions into smaller questions to find one that you can test. Consider the materials, tools and instruments that are available in your classroom. Consider materials, tools and instruments that you might bring from home, if what you have in the classroom is not adequate. Check in with your teacher about the availability of things you don't have. What is your working model for "seed sprouting"? Write down your research question. Check in with your teacher.

Example: Team Research Question: [write question here.]

Working Model: Describe. Include drawings and diagrams.

6. Design your experiment. Write up a template for your lab report.
A template is the format for your lab report. The template is a PLANNING TOOL for your experiment. It helps you gather the right equipment and have things ready to go. Items you know about and use for planning, such as materials, methods, empty charts and tables, etc. should be part of this template. You will fill in the data as you perform your experiment. An example is shown below.

Things to consider in constructing your template and 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 (a table)?
- Also remember that description (qualitative data) is just as valid numerical data. What kinds of observations can you make and record in your experiment?

Your lab report is still a draft! Do not worry if you need to modify as you actually run your experiment. But DO take the time to think this through carefully. Scientists do not want to waste time and expensive materials doing poorly planned and poorly thought out experiments.

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: Seed Investigation Preliminary Lab Report

Research Question: [State your team's question here.]

Prediction: What do you think the answer to your research question will be? Give your reasons for why you think this is so? Use your background research and what you know to support your predication.

If you don't have a strong prediction, just make one. Describe what you think the supporting and non-supporting evidence might be for your prediction. Science is about testing the prediction and it doesn't matter whether your prediction is right or wrong. What matters is that an answer is obtained that helps to create a bigger picture of what's going on and how things work.

Materials: Seeds (What kind? How much?)
Growth Chamber (How many?)
Instruments/Tools
Etc.

Methods: Step-by-step instructions for your experiment.

Consider the number of data points you will take for each measurement. Do scientists base their thinking on one point or do they do replicates? Why do you think they do replicates? Record your thought in your online journal.

Kinds of data: List the factors you think are important for your seed sprouting and the data that you want to record.

Formatted data: You might want to have some data in a table and other just listed. Create your formats ahead of time, so you aren't scrambling when you need to record something on a moment's notice.

Timeline: Create a schedule for each part of your experiment.
Day 1: Set up
Day 2: Collect and report data point X
Etc. How many days will you collect data? Will you have enough class time to do so? Check with your teacher.

7. Bullet-proofing your experimental design.
Go through each step of your experimental methods (step-by-step instructions). Picture each step in your mind. What materials do you need for that step? Is the material listed in your "Materials" list? Do you have units written down for your different types of data?

Make sure to consider the environmental factors in describing your experimental conditions for sprouting. Will you be doing your experiment in the light or dark? What instruments or tools will you use to make measurements and collect data? Be thoughtful and thorough in thinking through your experimental design.

8. Prepare to run your experiment.
Gather the materials, tools and instruments for your experiment. Have your data collection tables, charts, and etc. ready.

9. Start your experiment.
Create a Results section in your Preliminary Lab Report. Record the data in your online lab report.
- Date and time of data entry.
- Data

- 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 teacher if you can add the data some way to your results. This kind of careful observation and note-taking during an experiment can be a good source of new experiments and great discoveries later on!

10. Enter your data into your team's page at the Wonder of Seeds project on the BSA's website http://www.botany.org/scientific_inquiry/.

11. Analyze your data.
What you have collected 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. If you know how to use MS Excel to enter and graph data, do so. The Excel file can be sent to the website in place of entering the data on the data submission form.

12. Make meaning or sense of your data.
Look at your observations (descriptions) of change over time. Some observations will be descriptive text (words), while other observations will be numerical. What story do the non-numerical data tell? What story do the graphed numbers tell? Explain each in detail. What are you sure about in each of your stories and why? What are you less confident in each and why? Explain what your data says about seed sprouting. 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 this 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.

13. Prepare a scientific poster about your research.
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. Identical experiments lead to data that can be compared directly (or almost). When scientists perform experiments that ask slightly different questions, they work together to connect pieces of their model together. For instance, one lab's work might describe where a certain species of tree occurs around the world. Another group might find that a rare species of fungus grows under this species of tree. The tree group then finds that their tree species is threatened by clear-cutting in areas where this tree is found. The two teams of scientists then work together to determine whether the rare fungus will become endangered as a result of deforestation. In creating their models of how things work, scientists always use their data as evidence to support the model. Science is based on evidence, not on made-up fantasy. In science, we call the model is sometimes referred to as a working model or working hypothesis because as new findings are made, the model is modified to account for the new evidence.

14. Post your poster to the website.

15. 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?

16. Present your poster to the class.

17. Compare your data to other teams in the class.
This will be done as a class discussion. Use evidence (either from your experiments or others in the class) to back up your thinking.

18. Derive new questions from your experiments and experience.
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.

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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 automatically.

- 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.

HOORAY!! YOU'RE FINISHED!
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