BOTANICAL SOCIETY OF AMERICA

SPROUT INVESTIGATION
Instructor Pre-Inquiry Guide

This is an inquiry on seed germination and seedling growth. The lesson emphasizes inquiry and the scientific process.

Overview of lesson general features

- Entry point/Launch to content area
  This inquiry can be used as an entry point to a unit on plant growth and bioenergetics and/or one on the scientific process and enterprise. As a plant biology investigation, this inquiry can be a launching point for student-initiated inquiries that can take many directions at many different grade levels.

- Self-assessment and peer assessment as learning strategies
  Students are explicitly introduced to the inquiry cycle and the criteria for assessing their own work and that of their peers. This process promotes student reflection and awareness of their own thinking and reasoning.

- Scientific inquiry using plant examples
  Although plants are essential for life on earth, they are not well studied in today's science curriculum, and students often graduate from high schools, colleges, and universities having a generally poor understanding of the pivotal role plants play in world economics as a source of food, shelter, and energy. This lesson uses plants as an example in treading the path of scientific inquiry.

- Highlights research and the inquiry process
  Students will generate their own research questions using the Student Research Guide as a scaffold for the inquiry process. The guide is augmented by teacher-initiated activities interjected at various points in the lesson. The lesson is also augmented by interaction with scientists working in the area of plant biology, mathematicians who can help in the data analysis phase, and science educators who can address questions about inquiry in the classroom.

- Interdisciplinary nature of science
  The lesson also permits deeper discussions about the relationships between math and biology, chemistry and biology, and physics and biology. As a lesson on plant growth, proportionality (ratio of growth to mature plant height), rate (growth over time), chemistry (chemical composition), and force (seed germination) can be investigated.

- Technology embedded in investigation
  Technology is integrated through online discussions and peer reviews within a classroom, among classrooms at the same or different schools, across class levels,

among teachers, and among classrooms, teachers, and mentors. The website also houses classroom and teaching resources.

Enduring Understandings

- Because the world relies on seeds for food, the world economy is also dependent on plants.
- Seed dormancy and germination are reproductive and adaptive strategies, as well as dynamic processes responsive to the environment.
- Scientific inquiry uses evidence to arrive at new models for biological systems.
- Math is an important analytical tool in the analysis of evidence in science.

Essential Questions

- What role do seeds play in supporting life on earth?
- How does a sprout develop from a seed?
- What are the characteristics of seed germination and seedling growth?
- What role does the environment play in seed germination and growth?

Background

FOR INSTRUCTOR ONLY – DO NOT HAND OUT TO STUDENTS!

Bewley, J.D. 1997 Seed germination and dormancy. *Plant Cell* 9: 1055–66.

Guides to the Inquiry

Documentation for this inquiry includes one student guide and three instructor guides:

- Pre-Inquiry Guide (this document)
- Student Research Guide (Instructor's Version)
- Inquiry Teaching and Assessment Guide (instructor)—important to read before beginning student research as it contains background and activities that are conducted as part of the student research.

Within each document, there will be links to content, inquiry, and instructional tools and strategies to help inform the process. The Scientific Inquiry through Plants website will have links to references and resources of interest to both instructors and students.

Pre-Inquiry Engagement and Exploration

Day 1: Engage and explore prior knowledge (45 minutes)

Preparation: Soak each type of seed in water overnight (Quantities of each type of seed are specified in Seed Sprouting Kit). Do not discard water. Bring hydrated seeds and "seed water" to class for students to divide into their sprout chambers.

- **Introduce topic**
  Tell students that they will be investigating the topic of seed germination and seedling growth. Hand out the ABCNews article on lotus/Shen-Miller's work. Give students a few minutes to read the article.

- **Engage students**
  To engage students, give the example in the ABC News story (provided as an HTML file) about Jane Shen-Miller's work on lotus seeds (begins opening conversation about dormancy, stimulating seed sprouting, and medicinal plants). Have them openly talk about the science in the article. In a very natural way, connect the scientific observation or finding with the related component of inquiry (making observations, putting observation in context of other research, evaluating evidence, reasoning carefully, coming up with explanations based on evidence, etc.) that are brought out in this brief synopsis of Shen-Miller's work.

- **Connect lesson to everyday life and relevance to society**
  Brainstorm with students about other ways that seed biology and their sprouting ability might be important to society. (Examples: seed conservation, crop, ornamentals, tree farming industry, environmental studies, etc.) Avoid letting this section become an instructor-led lecture; ask questions to help students jumpstart their thinking. Help students clarify what they are saying and provide evidence for what they are saying. The evidence can come from personal experience/observation or known fact.

- **Probe for prior knowledge**
  Ask students what they know, think they know, and want to know (KWL) about "spouting seeds". These KWL questions are described at the end of this document. Again, the instructor should facilitate the discussion. (Note: In inquiry, we tend to leave vocabulary behind until students are clear on the concept. By doing so, discussion become rich in description of organisms, process and environment and don't minimize the concept with a label that might mean different things to different people.)

  Eliciting a student's prior knowledge is a critical step in learning and teaching. First, this process tells you where your students are in their knowledge and

thinking about the topic. Second, it also allows you to help the student clarify that knowledge or thinking, if it is unclear by the student's initial description. If the thinking or knowledge is a misconception, it is important for you to facilitate their learning such that the student can probe their own thinking and even conduct experiments that might change alter their thinking and mental model.

- **Explore seed diversity**
  At this point, have students examine the different types of seeds provided in the seed diversity packet of the sprout kit. Help students see the seeds are food sources either in their seed, sprout, or plant forms. Help students connect this lesson with their everyday lives—anything from eating sprouts to raising crops from seed to buying dried beans for chili (See "Strategies for Engaging Students" at the end of this document).

Day 2: Coming to a student-inspired research question
Note—Days 1 and 2 may be combined for longer class sessions.

Purpose: To engage students in thinking about research questions and facilitate inquiry into the dynamics of seed germination and seedling growth.

Preparation: Obtain computer access for student online journaling.

What to expect: Students will work in research **teams** of 2-4 students. Working in pairs often encourages students to more fully participate in the inquiry process. Nudge (but do not direct) students toward inquiries that focus on experiments that will measure seed viability, germination rates, stem elongation rate, and development in general. This team-to-team consistency will facilitate data comparison among teams. Students will use the Research Guide to arrive at their research question and to design their experiments. Students will journal online. During the journaling process, they will reveal their thinking and conceptual models. Teachers should provide students with online or classroom feedback on their journal entries in the form of thought-provoking questions to guide student thinking. The journal, along with teacher-initiated class activities, will provide a means for everyday and summative assessments (See Inquiry Teaching and Assessment Guide for details).

Now that the students understand that seeds are sources of food:

1. **Introduce research inquiry and materials**
   Tell students that they will be doing research on sprout growth. Show them alfalfa sprouts and have them discuss how edible sprouts are grown. The Student Research Guide has a protocol for growing edible sprouts. (If you wish to further

motivate students, you can also present the scenario in "Strategies for Engaging Students" to stimulate exploration of a research question.)

2. **Brainstorm**
   Facilitate a discussion on how students want to define what it means to "sprout" and "grow." This discussion will inevitably lead to, "What is a measure of "sprouting"? What is a measure of "growth?" This is the prelude to them thinking how they will recognize sprouting and growth and how they will measure them in their investigations. Write these ideas out on the board, as students discuss them, so that they can recall these discussions when they design their experiments. Remember, this in inquiry-based teaching and learning! At this point in time, **there is no "right" answer**. This is a brainstorming session in which students are to arrive at their own mental models for germination and growth. Time to germination, seed viability, dry mass change, and stem elongation rate are examples of measurements that reflect sprout growth. Environmental factors, such as light, soil, length of imbibing seeds (soaking in water), composition of soaking solution, might also play roles in expressions of "sprout growth." Hormonal controls are also key to germination.

3. **Discuss inquiry and the scientific process in the context of designing their experiments**
   Move on to the "Expectations" and Inquiry Cycle in the Student Research Guide (Teacher's Version) for flow and teaching tips. The guide will help you to decide when to call in experts to give students feedback, and when to provide students will guidance in class and online.

Days 3-12 or so Student Research

Day 13 Poster Preparation

Day 14 Presentation/Inquiry Assessment

Day 15 Class discussion—What do the class findings tell us about seed sprouting?

Strategies for Engaging Students

Connecting to student realities

Connecting to students' everyday lives creates relevance and motivation to learn. The importance of the topic to contemporary issues is a good way to engage learners. Newspapers and popular magazines, such as National Geographic and Smithsonian, often provide ripe fodder for introducing a topic. Keep a running file of articles that might be used to launch classroom discussion and investigations.

If you find articles related to the BSA Inquiries, please let us know so that we can post them to the Teacher/Classroom Resource.

Personal stories

The philosophy behind the BSA Inquiries is authentic inquiry. In authentic inquiry, students are investigating their own questions. Teachers/instructors model this self-initiation process by having their own questions arising from their personal experiences. For instance, the sprout investigation offers many ways to introduce seed diversity and seed germination. By taking a trip to the organic food coop to buy dried beans for chili to soaking the beans a little too long, teachers can reveal their own observations to students. And those observations give rise to the teacher's own questioning. An example of using a personal story is provided below:

Here is an **example** of a personal story that you can use.

> "I was in the grocery store the other day buying some beans for my chili. It was one of those stores where they have all of these clear bins with different kinds of dried beans, rice and grains in them. When I wasn't so focused on just the one kind of bean I was there to buy, I noticed the amazing colors, shapes and sizes." [Place examples on the table for students to explore. Start an activity in which students can "mess about" with the seeds and ask questions about them.]

Continuing the personal story to demonstrate how inquiries evolve from everyday experiences is also helpful. Continuing the example story, you might say, "I also wondered what we are eating when we eat these? And why do I have to soak my chili beans overnight to eat them? What do you think?" Or for more advanced students, more sophisticated observations may be called for.

The students may respond that you would be eating rock-hard beans, if you don't soak them. Probe this line of thinking for reasons that soaking may soften the beans. Students will often offer explanations based on their prior knowledge of seed germination or personal stories, which can be probed. Use this as the basis for a short investigation on seed anatomy and germination. Does soaking seeds just hydrate or something else

happen? Look at the "bean water" after an overnight soak. What does it look like? What does the endosperm look like after the overnight soak? Some simple dissections and observations can help students sort out what they think is happening from what they observed has actually happened. What simple chemical tests would help identify the composition of "bean water"? Students may think they know what bean water is made of. If so, ask how they could test their ideas.

Scenarios

Scenarios are often used to motivational or engagement tool. Crime/forensics scenarios with a mystery flavor are popular. Though scenarios can work very well as a starter for a laboratory investigation, they run the risk of being contrived and artificial. Here is a scenario for the sprout investigation that could tie connections to a class in the business department, which can create a business plan, and your botany class. A business plan will consider what one needs to do to maximize profit (sprout production).

Here is an **example** of a scenario that you can use.

> Your class is going to start a new business. You will be selling different types of salad sprouts to organic food markets and salad bars in your area. In order for your business to be successful, you need to learn more about how to "make" sprouts as fast as possible.

KWL Chart

KWL stands for what students know, think they know (but are not certain they know), and want to know or learn. KWL is a commonly used tool for eliciting students' prior knowledge, i.e., what the student knows when he/she starts a unit. KWL can work in the undergraduate classroom, whether a large lecture or small lab setting.

Create a chart on the board:

Know	Think We Know	Want to Find Out

Assuming that the unit topic has already been introduced, the instructor asks the students what they know, think they know and want to find out about the topic, e.g. seeds and how they "sprout."

As students reveal items, the instructor writes them in the appropriate column in the chart. Students should also ask how they know that fact, if further explanation seems warranted. For example, a student might say something that leads you to believe that seeds form embryos de novo upon being imbibed. In response, you might ask the student what they think is in the dry seed, which gets at the student's conceptual model of the seed.

Once the KWL activity is completed, the instructor can leave it up for student reflection as the lecture or lab investigation continues, which might be some weeks. An option is to move items from "think we know" to "know" and so forth as the class learns more.

[Note: In inquiry-based teaching, vocabulary is introduced AFTER the concept has been discovered by the students and connections made to larger conceptual frameworks. That is, things and processes are labeled after students have an understanding of what "it" is or how "it" works. The rationale behind this approach is that students are less likely to call something by a name and mean something different, thus confounding the learning process.]

Some Student Misconceptions
From a website reviewing student performance on the Hong Kong biology exam
http://www.fed.cuhk.edu.hk/%7Ejohnson/misconceptions/ce/misconceptions/mis_in_bio/reproduction_and_development.htm

"Measurement of growth
"Many students consider that the growth of a germinating seed can best be measured by the increase in dry mass. Although the change in dry mass is normally considered to be an accurate method of measuring growth, it is not so in this particular situation. During seed germination before the development of green foliage leaves, the seed uses up stored organic food for respiration and for the formation of new tissues. In this case, growth occurs rapidly and this is indicated by the increase in fresh mass, in the length of the stem and root, but not in the dry mass, which is actually decreasing. There is no corresponding increase in dry mass during this period. When teaching the various methods of measuring growth, teachers should discuss the relative advantage and disadvantage of each method and point out that certain methods are suitable for measuring growth under certain situations but would be inappropriate in others.
"The poor understanding on the concept of dry mass is further reflected from the answers to the question *why there was a decrease in the dry mass of the seeds during germination*. A considerable number of candidates stated wrongly that the decrease in dry mass during germination is due to the evaporation of water. Some stated vaguely that the stored food is used for growth without specifying whether the food is used for respiration or for the formation of new cells.

"Seeds and fruits
"Many students have difficulties in distinguishing between a one-seeded fruit from a seed, e.g. maize/sunflower grain and a water melon seed. A seed has a scar left from breaking the placenta, which attaches the ovule to the ovary wall. A fruit, on the other hand, has two scars, one from the remains of the style and one from the attachment to the receptacle. Another feature of a fruit is that it normally has two layers of wall covering the seed. The outer layer is the fruit wall or pericarp while the inner layer is the seed coat or testa. A seed, on the other hand, possesses only the testa around the embryo. The presence of two covering layers is obscured in the maize grain, which is a one-seeded fruit, due to the fusion of the pericarp and testa."