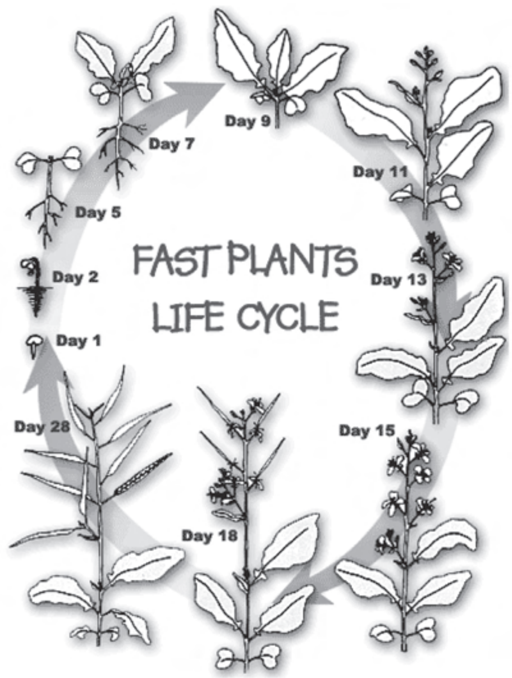
Exploring Variation and Natural Selection with Fast Plants



7th Grade Immersion Unit

Award No. 0227016

SYSTEM-WIDE CHANGE FOR ALL LEARNERS AND EDUCATORS
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Exploring Variation and Natural Selection with Fast Plants

Please note the following is an excerpt from a 7th grade Variation and Natural Selection Immersion Unit (extended investigation in science). This unit was developed in partnership with the Los Angeles Unified School District and is being tested and revised by teachers, scientists, and curriculum developers associated with the NSF-funded Math/Science Partnership, System-wide Change for All Learners and Educators (SCALE) and the DOE-funded Quality Educator Development (QED) project at the California State University – Dominguez Hills.

Special thanks to The Jane Goodall Institute (www.janegoodall.org) and Dr. Jane Goodall, DBE —Founder, the Jane Goodall Institute—for granting permission for us to use a page from her science journal in Step 1, Lesson 3: Science Notebooks: Communicating and Recording.

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STEP 1

Overview

In this step, students practice the skills they will need to work as scientists later in the unit when they design and conduct their own investigations on variation in a population of Fast Plants. The opening question, “How Fast are Fast Plants?” provides an opportunity for students to gain experience asking a scientific question, making methodical observations, making and organizing notebook entries, and analyzing data as well as building and communicating evidence-based explanations.

From the opening of lesson one, students are introduced to Paul Williams, a creative scientist whose work with Fast Plants provides the students with background information on the development of the plant. Throughout the unit, students are able to use examples set by Paul Williams as a model to help them conduct their own investigations.

The students and teacher set up the experiment to test “How Fast are Fast Plants?” during one class period and start the investigation over the next day. Then students make observations and complete the first investigation during the first week. Students will continue to make observations and notebook entries on the Fast Plants as they continue to grow and develop in the following weeks as the class progresses through the unit.

Key Concept

Fast Plants are a special kind of plant that a creative scientist developed by doing science to produce a plant that grows quickly in artificial conditions.

Evidence of Student Understanding

The student will be able to:

- explain the origins of Wisconsin Fast Plants
- plant Fast Plants according to the Fast Plants Planting Protocol

Time Needed

50 minutes

Materials

For each student
- 1 copy of Student Page 1.1A ***Fast Plants Planting Protocol***
- 1 copy of Student Page 1.1B ***Petri Dish Germination Protocol***
- 2 note cards (optional: 2 different colors)

For each of 4 students
- one growing quad
- 10 Fast Plant seeds (2 for each quad cell and 2 for the Petri dish)
- potting mix
- lighting
- watering system
- fertilizer pellets
- 1 Petri dish
- paper towel circles cut to fit Petri dish

For the class
- 6–8 quads for the teacher to plant without fertilizer
- 1 copy of Teacher Page 1.1a ***Preparing for Students to Plant Wisconsin Fast Plants***
- 3–4 Petri dishes with paper towel and seeds that will not be moistened (to use in Lesson 2)

How Fast are Fast Plants?

1. To introduce and build enthusiasm for the unit, explain that in this unit students will be working like scientists to understand how important variation is in a population, even designing and conducting their own investigation using Fast Plants. Begin a quick whole-class discussion, posing questions like:

- What kind of variation do we see among the individuals in our class? That is the kind of thing we are going to study for in this unit!
- Why do you suppose the plants we are going to study are called “Fast” plants?
- What do you think of when you think of a plant being “fast”?

2. Remind students that they are going to work like scientists during this unit. Ask the students ”What do Scientists do?” Chart responses. Be sure to add or emphasize that scientists communicate with one another to explain their work based on evidence.

3. Briefly explain that throughout this unit the class will hear from the actual scientist who developed Fast Plants. To begin to learn what students already know, have students individually write ***one*** *sentence on a note card* answering:

- How can a scientist “develop” a new type of plant like a “Fast Plant?”

Ask a few volunteers to read their statements. Collect the note cards for use in Step 2 (include students’ names on cards).

4. Show the video introducing The Father of Fast Plants, Paul Williams.

(continued on following page)

- After the video, pose the question: **Just How Fast are Fast Plants?** Have students record their predictions on a note card (include names) and collect for use later in Step 1.
- Explain that the class will grow their first crop of plants to learn the answer to that question and to get good at growing the plants for their later investigations.

5. Remind students about how Paul Williams selected for Fast Plants to grow under special conditions that would be handy for his work.

- Brainstorm plants' "needs" for growth and development and how Paul met those needs for selected Fast Plants.
- Emphasize the importance of following the same planting/growing procedures so that the class's plants are all growing under the same conditions.

6. Display the materials for planting and have students review Student Page 1.1A *Fast Plants Planting Protocol*. Allow students to ask questions about the protocol and highlight key points from the planting procedure.

7. Explain to the class that to see what happens to Fast Plants before they emerge from the planting mix, some will be placed on moist paper towel in Petri dishes. Provide a quick demo, and tell each group set up one Petri dish when planting their Fast Plants in planting mix.

- Distribute Student Page 1.1B ***Petri Dish Germination Protocol***.

8. Have groups of four students plant seeds in 1 quad according to the Planting Protocol and prepare 1 Petri dish as previously described.

- Note: *Resist the temptation to provide students with guidance for recording notes or observations until the next lesson.*

See Advanced Preparation section for notes about the different protocol for seeds planted by the teacher.

9. Use the REAPS questions throughout the lesson where appropriate.

REAPS Questions

R **What do Fast Plants need to grow and develop well?** Fast Plants do best when they are grown as described in the Growing Protocol with planting mix, fertilizer, water, and light.

E **Compare the growing environment of Fast Plants to another plant you are familiar with—how are they similar and different?** Look for similarities like: they both need fertilizer, light, water; and look for differences like: Fast Plants grow indoors, do best with 24 hour light, and use very little soil.

A Students will analyze their understanding in later lessons.

P **What do you think will be the first change in the Fast Plant seeds?** Use student responses to informally assess their understanding of germination and plant growth.

S **What did you do today that was like what a scientist does?** Look for responses like, "I used a protocol, I wondered about how a plant grows, I made a prediction."

Advance Preparation

Remember to **start the unit on a Monday** so the plants will be ready for student investigations on weekdays when students are in school.

NOTE: On the same day that students plant their Fast Plant seeds, you will need to plant 6–8 quads of Fast Plants yourself using the *Fast Plants Planting Protocol* with one exception: **DO NOT ADD FERTILIZER**. Keep these quads on a separate water reservoir so that they receive no traces of fertilizer. In Step 2 Lesson 1, the class will investigate what may have happened to cause these plants to grow and develop differently than the students' plants. After 9–10 days, the plants without fertilizer will be significantly different; for example, they will be shorter, have paler leaf color, and yet will have similarly-timed life cycle stages.

If you have never planted Fast Plants before, preparing these 6–8 quads will help you to prepare for assisting students as they plant, so we recommend doing this in advance.

Plan the following in advance:

1. Decide how you will group students.

2. Set up video introducing Paul Williams and Fast Plants.

3. Prepare for planting:
    - set up florescent lights
    - organize the materials students need for planting (see Teacher Page 1.1a *Preparing for Students to Plant Wisconsin Fast Plants*)

4. Set out materials needed to grow seeds in Petri Dishes for the first week:
    - Petri dishes
    - Fast Plant seeds
    - paper towels (you may wish to cut Petri dish-sized circles of paper towels in advance to save time)
    - waterproof markers

5. Make copies of Student Page 1.1A ***Fast Plants Planting Protocol.***

6. Set up materials to demonstrate key planting procedures: 1 quad, planting mix, water, fertilizer pellets, Fast Plant seeds.

7. Plant 6–8 quads of Fast Plants yourself without fertilizer (see special NOTE earlier in the Advance Preparation section).

8. Set up materials to demonstrate placing seeds in a Petri dish to germinate: 1 Petri dish, 1 paper towel, 5 Fast Plant seeds, a dish to place the Petri dishes in to wick moisture (see the Petri Dish Germination Protocol).

9. Prepare 3–4 Petri dishes that will not be moistened to use in Lesson 2 so that students can directly observe how the seeds change over night.

NOTE: *The seeds in Petri dishes are intended to be observed only until the seeds emerge from the planting mix in the quads. If some students have poor germination in their quads, seedlings from the Petri dishes can be carefully transplanted into empty cells.*

Teacher Background Information

The plants used throughout this unit are Wisconsin Fast Plants, chosen because of the ease with which they can be grown in the classroom and their quick life cycle. Fast Plants (scientific name: *Brassica rapa*) are rapid-cycling brassicas. They are members of the crucifer family of plants, closely related to cabbage, turnips, broccoli and other cruciferous vegetables. Bred for over 30 years at the University of Wisconsin–Madison by Professor Paul H. Williams, Fast Plants today require little more attention than continuous fluorescent light, water, and fertilizer. The seeds that you grow in your classroom can be immediately planted or stored for up to 10 years in a refrigerator.

The video segment included with this step features Paul Williams. By providing videotaped descriptions of his work developing Wisconsin Fast Plants, this unit takes advantage of this opportunity for students to understand science as an ongoing and dynamic quest to understand the natural world.

Planting Fast Plants on this first day of the unit is designed to accomplish several important and necessary outcomes:

1. Students (and teachers) are immediately introduced to the organism they will be working with throughout the unit.

2. Students learn the planting protocol and practice growing Fast Plants so they are better prepared when they design their own experiments.

3. The Fast Plants needed for Step 2 are planted with sufficient time to grow to the necessary size.

Additional information about Wisconsin Fast Plants—growing options, tending tips, research, and activities—is freely available at *www.fastplants.org*.

This unit involves a great deal of interaction among students and between students and the teacher. So you may want to:

- Set up the classroom so students can quickly and easily shift from working alone to working in groups of four.
- Point out to students that a big part of working as scientists is communicating with other scientists. Scientists are constantly talking with each other and sharing information and learning from each other. **Prepare students to expect an interactive unit—one where they will need to communicate with each other to work through their investigations. As scientists, they will attempt to do problem-solving with other students rather than the teacher.**

NOTE: ***In this lesson, the teacher is instructed to secretly plant 8 quads of Fast Plants WITHOUT any fertilizer. In Step 2, a question about why the teacher's plants are different will be posed to students, and the teacher will provide a situation where students must use experimental data to develop an explanation for what happened.***

Implementation Guide

1. Quickly engage students in understanding that during this unit they will work as scientists to conduct their own investigations with a cool plant known as Fast Plants.

They will also learn about variation. Begin a quick whole-class discussion, posing questions like:

- What kind of variation do we see among the individuals in our class? That is the kind of thing we are going to study for in this unit!

Encourage students to look around the classroom at the many different heights of their classmates, the many different hair colors, hair curliness or straightness. These are variations of traits. Briefly mention to students that they will design their own investigation to look at the variation of traits in Fast Plants. Ask the class:

- Why do you suppose the plants we are going to study are called "Fast" plants?
- What do you think of when you think of a plant being "fast"?

2. Remind students that they are going to work like scientists during this unit. Ask the students "What do Scientists do?" Chart responses. In order to begin to set the tone for how this unit will be executed in the classroom add or emphasize that scientists communicate with one another to explain their work based on evidence. In addition, mention that the students are the ones who will be discussing the work and the teacher is the facilitator of the discussions. Post the chart paper on the wall for the duration of the unit. Refer to and add to the list as necessary.

3. Explain to students that they will have an opportunity to hear from the actual scientist who developed the Fast Plants—the plants they are using in their investigations. To begin to learn what students already know, have students individually write ***one*** *sentence on a note card* answering:

- How can a scientist "develop" a new type of plant like a "Fast Plant?"

Collect the note cards for use in Step 2 (include students' names on cards).

Ask a few volunteers to read their statements. As students offer explanations, resist the temptation to explore their ideas at this time. This is only intended to assess students' current understandings. Encourage students to keep what they wrote in mind as they watch the video and investigate Fast Plants.

4. Show the class the video introducing The Father of Fast Plants, Paul Williams. In his last words on the video, Paul begins to talk about how short the life cycle is for Fast Plants. After the video, give each student another note card and pose this question to the class:

- ***Just How Fast Are Fast Plants?***
- Then have students write a one-sentence prediction on the note card and put their name on the card.
- Collect and keep these cards for use later in Step 1, Lesson 3, when students will add them to their science notebooks and then refer back to them in Lesson 5.

Explain to students that it is now time to plant their first crop of Fast Plants. They will use them to answer the question, ***How Fast Are Fast Plants?*** and to get practice growing these plants, because later they will be using them in their own investigations.

5. Bring students back to the idea that Paul Williams mentioned in the video. Remind students that when he developed his line of Fast Plants, he selected plants that would grow under special conditions that would be useful for his work.

Facilitate a discussion to help students explore how he met the needs of Fast Plants in his laboratory and compare it to how plants typically get their needs met in nature.

Brainstorm with students about what plants need to survive. Draw a three-column table and work with the whole class to fill in the table. For example:

Environmental needs of plants	How the natural environment meets needs of wild type Fast Plants	How the artificial environment in Paul William's lab meets the needs of Fast Plants
sunlight	sunlight	florescent light/commercial light
soil	soil	commercial planting mix
water	rainfall, groundwater, etc.	water from faucet
nutrients	nutrients in soil	fertilizer
air	air	air

Explain that students will use the same protocol that Paul Williams used to grow Fast Plants so that their specific needs are met. A ***protocol*** is a detailed plan for how to perform a task.

Emphasize the importance of following the same planting/growing procedures so that the class's plants are all growing under the same conditions. This way we will know that any differences we see among plants probably are not due to differences in how the plants were raised.

6. Display the materials for planting in the front of the classroom, and distribute copies of Student Page 1.1A *Fast Plants Planting Protocol*. Have students read the instructions and talk with a neighbor about any questions they have.

With the class, highlight these key points in the planting procedure:

- Make sure that the wick extends enough to make contact with the mat on the water reservoir. The wick also needs to be saturated with water.
- DO NOT pack the planting mix. Sprinkle the mix in place; it will settle when it is watered.
- Notice that the fertilizer pellets look like seeds; however, Fast Plant seeds are much smaller.
- There is a layer of planting mix between the fertilizer pellets and seeds so that young roots do not get burned by the fresh fertilizer.
- Cover seeds lightly with a thin layer of planting mix.

7. Explain that to see what happens to the Fast Plant seeds before they emerge from the planting mix, some will be placed on moist paper towel in Petri dishes.

Direct each group of four students to start seeds in one Petri dish after they plant their seeds in potting mix (one quad per group). Provide a quick demonstration of how to set up the Petri dish. Distribute Student Page 1.1B *Petri Dish Germination Protocol.*

- These will be used only during the first week of the unit. However, seedlings can be carefully transplanted from the Petri dishes into quads late in the week if needed.

8. Have students in groups of four plant seeds in 1 quad according to the Planting Protocol and prepare one Petri dish with seeds to germinate. As students plant, travel from group to group to ensure students are following the details of the protocol. Direct students to label their plants and place the quads under the florescent lights.

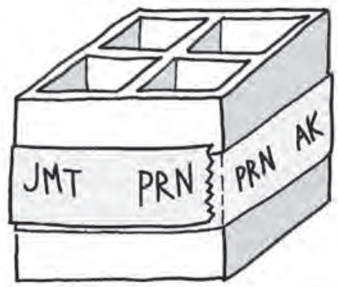
Resist temptation to provide students with guidance for recording notes or observations until the next lesson. During the next lesson, they discover for themselves why keeping a detailed and accurate science notebook is critical.

9. Use the REAPS questions throughout the lesson where appropriate.

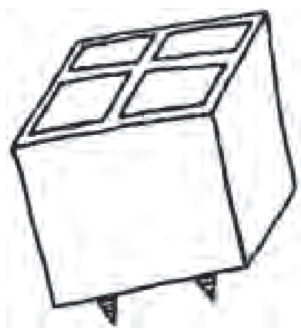
On the same day, plant 6–8 quads yourself using the same Fast Plant Planting Protocol with one exception: add NO fertilizer. In Step 2 Lesson 1, the class will investigate what may have happened to cause these plants to grow and develop differently than the students' plants. See the ***Advance Preparation*** section for more details.

Student Page 1.1A: Fast Plants Planting Protocol

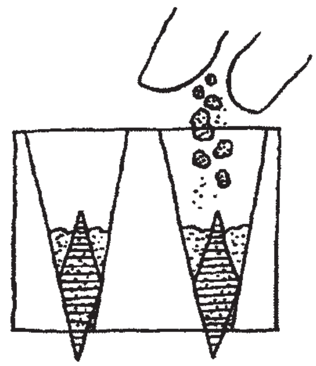
1. Label each cell as your teacher directs so that every student will know which plant is hers or his.



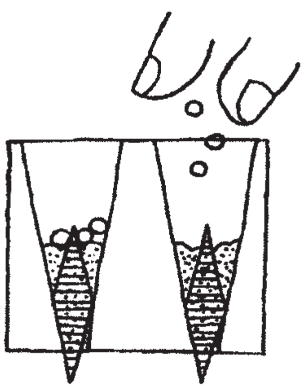
2. Drop one wet wick into each cell so that the tip extends 2 cm out of the hole in the bottom.



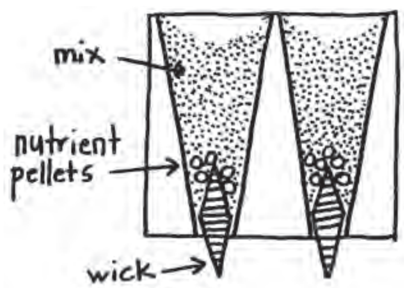
3. Fill each cell halfway with slightly moistened planting mix.



4. Add 3 pellets of fertilizer to each cell.

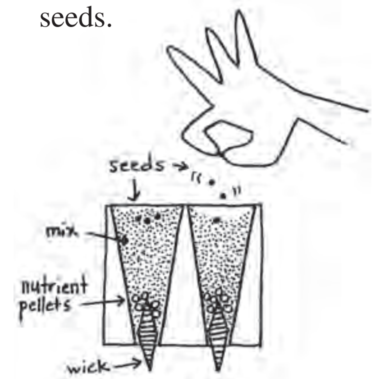


5. Fill each cell nearly to the top with planting mix.

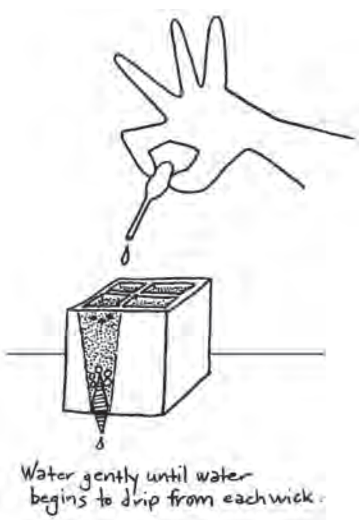


6. Drop 3 seeds on top of the planting mix.

- Fill to the top of each cell with mix to just cover the seeds.

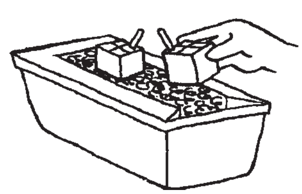


7. Water very gently with a pipette or dropper.

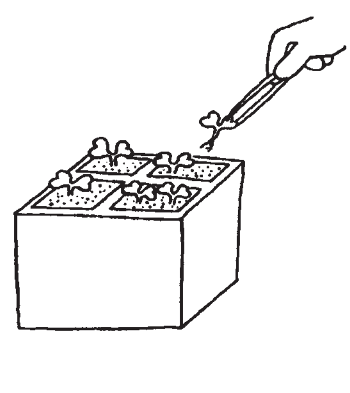


8. Put your group's quad on a water reservoir as your teacher directs.

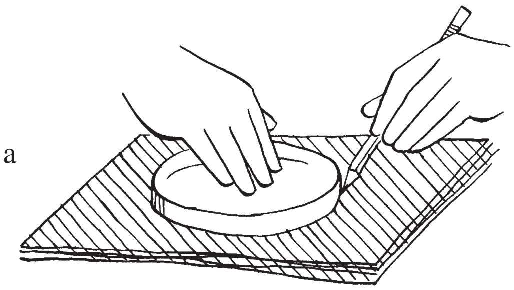
- The class quads (on their reservoirs) will all be placed under fluorescent lights that are on 24 hours/day and kept 5–10 cm from the top of the plants.



9. Use tweezers or scissors to thin to one plant per cell when your plants have just pushed through the planting mix.



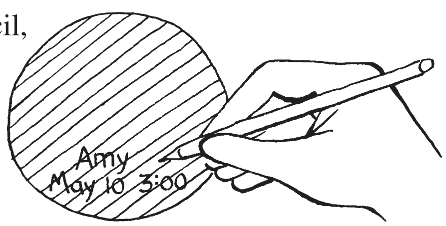
Student Page 1.1B: Petri Dish Germination Protocol



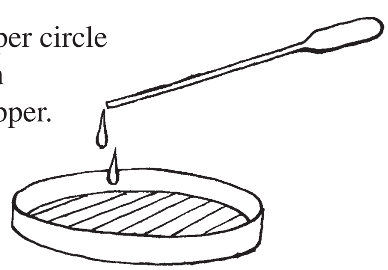
1. From a paper towel or a piece of filter paper, cut a circle 8.5 cm in diameter to fit in the cover (larger half) of a Petri dish.

2. Fold the paper towel circle in half. Use a pencil to draw a straight line where you folded the circle in half.

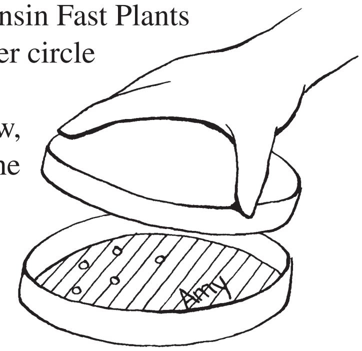
3. With a pencil, label the bottom of the paper circle with your name, the date and the time.



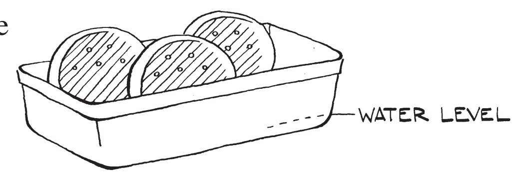
4. Moisten the paper circle in the Petri dish with an eyedropper.



5. Place five Wisconsin Fast Plants seeds on the paper circle along the middle line that you drew, and cover with the bottom (smaller half) of the Petri dish.

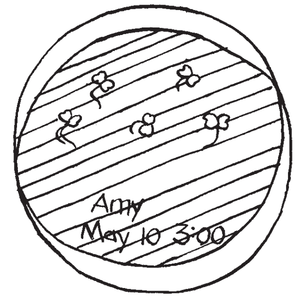


6. Place the Petri dish at a steep angle (80˚– 90˚) in shallow water in a tray so that the bottom two centimeters of the paper is below the water's surface.



7. Set the experiment in a warm location (optimum temperature: 65–80˚F). Check the water level each day to be sure the paper circle stays wet.

8. Over the next 3–4 days observe the germinating seed and seedlings using a magnifying lens.



NOTE: Germinated seedlings can be carefully transplanted into quads at Day 5 and grown to maturity. This may slow the developmental cycle by a few days.

Teacher Page 1.1a: Preparing for Students to Plant Wisconsin Fast Plants

Materials for planting and growing Wisconsin Fast Plants using The Wisconsin Fast Plants Growing System

The growing system components and lighting are ordered from Carolina Biological Supply Company, and include everything you need to successfully grow Fast Plants. Unless otherwise specified, Classroom Kits are designed for use by up to 32 students working in pairs. Planting and growing instructions for the Wisconsin Fast Plants Kits are provided with purchase.

The following materials are included in the growing system:

- Wisconsin Fast Plants seeds, rapid-cycling *Brassica rapa* (Rbr). (Seeds are small and need to be handled with care.)
- quads—4-celled planting units in which you will grow one plant to maturity in each cell
- planting mix (NOT planting soil)
- diamond wicks—conduct water from water mat to planting mix in cell of quad
- water mat—conducts water from reservoir to wicks
- fertilizer pellets—slow-release source of nitrogen (N), phosphorus (P) and potassium (K). Pellets are larger than the seeds.
- plant labels—to record student name, planting date and experiment *(note: see comments in #6 of Advance Preparation Table)*
- pipettes or droppers—to water cells from above when necessary
- dried honeybees—to make beesticks for pollinating
- algae-squares (tinged blue)—contain copper sulfate to prevent algae growth in reservoir
- water reservoir
- wooden stakes and plastic support rings—to support the plants if necessary *(use at the very first sign of plants leaning)*

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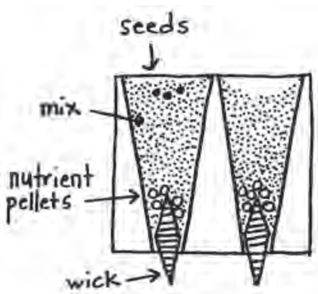
Teacher Page 1.1a: Preparing for Students to Plant Wisconsin Fast Plants

(continued)

Advance Preparations for Planting

1. Obtain seeds and growing system materials:

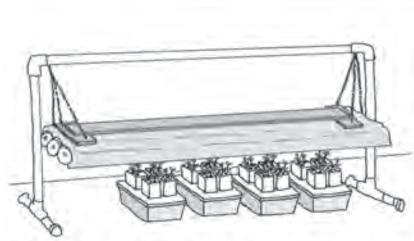
- 2–3 seeds per student
- 1 quad for each group of four students
- 4 wet wicks for every quad
- 1 water reservoir for every 8 quads



2. Assemble lighting system if necessary.

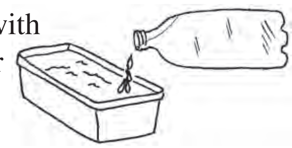
Determine how you will adjust the distance from the light to the plants.

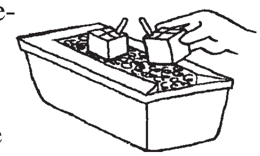
- You must either raise/lower the water system with quads or raise/lower the lights.



3. Prepare water reservoirs:

- Fill with water and drop in algae-control squares.

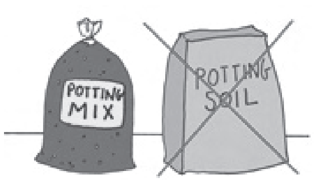




- Saturate the water mat and lay it on the reservoir lid with one end of the mat extending into the water through the slot cut in the lid.

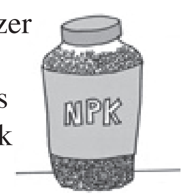
4. Pre-moisten a large container of planting mix for use during planting.

- Planting mix needs to be just moist enough to feel wet and not clump together.
- Prepare to give each group of four students a Pipette or dropper to water their cells gently after planting.



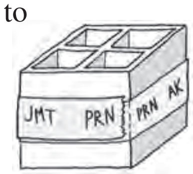
5. Determine how you will dispense seeds to students to minimize loss and waste.

- You may wish to hand seeds out individually to students just as they are ready to place seeds in the quads during planting.
- Also, plan for distributing fertilizer pellets and making it very clear to students that the fertilizer pellets are NOT the seeds (they may look like seed to a novice).



6. Determine how students will label the quads so that they know which plant is theirs. This is important for making accurate observations and building interest in tracking their own plant. Recommended:

- Wrap the quad in masking tape several times so it stays in place when wet, and have students write initials on the masking tape with permanent marker or pencil. (This is easy to remove later to re-use the quad.)



Key Concepts
- Scientists' explanations about what happens in the world come partly from what they observe, partly from what they think.
- What people expect to observe often affects what they actually do observe. Strong beliefs about what should happen in particular circumstances can prevent them from detecting other results.

Evidence of Student Understanding
The student will be able to:
- explain the difference between making scientific and casual observations

Time Needed
50 minutes

Materials
For each group of 4 students
- 1 planted quad (labeled) from the previous lesson
- 1 Petri dish with seeds (labeled) from the previous lesson

For each student
- 1 note card

For the class
- 3–4 Petri dishes with paper towel and seeds that were not moistened (to look as they did in Lesson 1)

Scientific versus Casual Observations

1. Remind students that in the previous lesson they started exploring questions such as:

- How can a scientist “develop” a new type of plant like a “Fast Plant?”
- Just How Fast are Fast Plants?

2. Encourage curiosity about what has happened to the seeds planted yesterday. On a note card, have students individually write one sentence about what they think has happened to the seeds from the previous lesson.

- Reinforce that the class is growing this first crop of plants to learn the answer to the question **Just How Fast are Fast Plants?** and to improve their skills at growing the plants for their later investigations.

3. Allow student groups 4–6 minutes to observe and discuss the changes in the quads and Petri dishes. Refrain from giving directions about recording data or being systematic about observations.

4. Remove the quads and Petri dishes so they cannot be seen, and ask the class a series of probing questions that will be difficult to answer without carefully made and recorded observations today and during the previous lesson. Ask questions like:

- How have the seeds changed since yesterday (color, size, position, moistness)? How do you know?

5. Ask students what would have made it easier to make reliable observations of what ***changed*** during the past day. Have students provide specific examples of difficulties they had trying to respond to the questions you posed based on their current observations.

(continued on following page)

6. Use a Think-Pair-Share strategy to develop a class list of criteria for making and recording good observations. Guide the discussion to include criteria such as:

- some observations need to be repeated every time for comparison
- drawings made to record scientific observations are realistic and made to scale
- (see the Implementation Guide for more suggestions)

7. Hand the plant materials back out to groups so they can make observations to more accurately answer the questions, ***How have the seeds changed since yesterday (color, size, position, moistness)? How do you know?*** Circulate among groups and check for accuracy and improved observing.

8. Use the REAPS questions either as a written exercise or oral discussion, and guide students to compare their own experience with observations to what scientists experience.

REAPS Questions

R **What is growing from the Fast Plant seeds?** Newly developing plants are growing from the seeds.

E **Compare what happens when scientists make observations and they already have a strong idea what they are looking for to when they don't have any idea what will happen?** When scientists make observations when they have strong ideas what to look for, those ideas may influence what they see, and their interpretations may be wrong because of that. Scientists try to be aware of their preconceived notions so that they can make observations without be influenced by their prior ideas.

A **Look at the sentence that you wrote before making any observations that described what you expected would have happened to the seeds. How did what you expected influence what you observed?** Students may realize that their ideas about what was likely to happen during germination may have influenced what they observed.

P **What difference do you expect to see between the seeds growing in planting mix and the seeds growing on paper towel?** Students may predict whatever they think with a reason.

S **How do you work differently when you make careful observations compared to when you make casual observations?** Look for responses such as, "I used a protocol, I wondered about how a plant grows, I made a prediction, I take notes in my science notebooks, I draw things to scale and the right colors, I measure things.)

Implementation Guide

In the first part of the lesson, students are directed to make observations of the Fast Plants and seeds in Petri dishes; however, they are not given instructions about how to make observations or to make notebook entries. After making observations, they are given questions that are likely to be difficult to answer from casual observations.

The goal of this experience is to make a strong case for setting standards for how observations are made and recorded. The class will then develop criteria for observations, setting expectations for how observations will be made throughout the unit. Using these criteria, the students will repeat the observation and questions.

1. Bring students back to where they left off by raising two questions that were posed the previous day:

- How can a scientist develop a new type of plant?
- Just how fast are fast plants?

Remind students to keep these questions in mind as they continue.

2. Raise the students' curiosity about how the Fast Plants may have changed since they were planted the previous day, by holding up one of the Petri dishes and asking, ***What do you expect to see when you look at the seeds today?***

- Pass out note cards and direct students to write one sentence about what they think happened during the past 24 hours.
- As students write, travel around the room and read over the shoulder of students to see if you can get an indication of what students understand about seed germination.
  - Resist the temptation to tell students what they ought to expect to see, and do not validate incorrect responses. Rather, acknowledge that this is just a prediction and may or may not be supported by what is observed.
  - Make a mental note if some students need additional instruction about how plants emerge from seeds. It will be important to support their learning this so that they can grasp in this unit how the environment influences growth and development for individual and populations of plants.
- Instruct students to keep their note cards for now because they will use them again in a few minutes.
- Reinforce that the class is growing this first crop of plants to learn the answer to the question **Just How Fast are Fast Plants?** and to improve their skills at growing the plants for their later investigations.

3. Pass out the quads and Petri dishes to the groups and instruct students to make observations. **Remember**: Allow students to make and record observations however they choose; later you will instruct them on how to make systematic observations.

- Allow 3–5 minutes for students in groups to observe and discuss their observations.

4. Next, remove the quads and Petri dishes from the students' sight and ask students a series of probing questions that would be challenging to answer without making methodical observations and records. The purpose of this is to allow students to experience the difficulty of remembering details accurately when making casual observations. This experience is intended to build awareness of the value and importance of scientifically oriented observations. Ask the questions:

- How have the seeds changed since yesterday (color, size, position, moistness)? How do you know?

Have students write their answers to these questions on the opposite side of the note card they wrote on earlier.

- Students need to keep these note cards for students to revise in #7 below, and in Lesson 3, they will add them to their science notebooks.

5. Ask students what would have made it easier to make accurate statement about what changed during the past day.

- During the discussion, have students refer to specific examples of challenges they faced trying to recall details.
- Make sure that students understand that it would have been easier to make a comparison of the seeds on the two days if they had careful observations from both days to compare.

Explain that you have several Petri dishes with seeds and no water added from yesterday that the students could use to repeat their observations after the class establishes criteria for making observations.

6. Use the Think-Pair-Share strategy for students to develop a class list of criteria for good observations. Prompt students to think about what makes a good observation by asking such questions as "How can you make and record observations so that days or weeks later you will still remember what you saw?" Guide the class discussion about what makes an observation reliable so it includes such criteria as:

- Observations are made and recorded the same way each time so students know that any differences are not due to how observations were made.
- Measurable traits, such as height and weight are measured using the same guidelines every time. For example, how do you measure the height of plant? From the planting mix to the top of the plant? Or from the roots up to the top of the plant?
- Traits that cannot be measured, such as the hardness of a seed, are compared to the same standard. For example, the hardness of seeds can be compared to the hardness of the same dry seeds every time. This way, differences probably are not due to inconsistent comparisons.
- Notes include comments about whether an observation is casual or methodical.
- Notes include comments on whether something is described from an actual observation or is an inference.

Save the class-generated criteria for making and recording high quality scientific observations as a reference.

> ***Evidence*** in science is gathered directly when we make observations of the natural world using any or all of our five senses. Evidence can also come from credible accounts of direct observations that were made and recorded by others. When evidence is gathered directly, it is considered primary source evidence. When evidence is collected and reported by someone else, it has then gone through their interpretation and is no longer considered primary source evidence.
>
> An ***Inference*** is an interpretation of evidence. We make inferences by comparing and judging evidence against our past experiences.

7. Pass out Fast Plant Petri dishes and Fast Plant growing quads again to their respective groups for students to practice methodical observing to answer the questions, ***How have the seeds changed since yesterday (color, size, position, moistness)? How do you know?*** Circulate around the room and check for improved observation techniques.

8. Use the REAPS questions either as a written exercise or an oral discussion and guide students to compare their own experience with observations to what scientists experience.

Key Concepts
- Clear communication and accurate record keeping is an essential part of doing science

Evidence of Student Understanding
The student will be able to:

- make science notebook entries using the class criteria effectively

Time Needed
50 minutes

Materials
For each group of 4 students
- their 1 quad of growing Fast Plants
- their Petri dish with growing Fast Plants

For each student
- science notebook
- 1 copy of Student Page 1.3A *Sample Science Notebook Pages*

Science Notebooks: Communicating and Recording

1. Explain to students that in this lesson the class will explore how scientists use scientific notebooks and focus on the question, **Why is a science notebook such an important tool that nearly every scientist uses one?**

2. Use a Think-Pair-Share strategy to learn what prior experiences students have had with keeping a notebook for science.

- Have students individually write three things that are important to include in a science notebook.

3. Explain that nearly all scientists keep a science notebook. Share the sample notebook pages on Student Pages 1.3A: *Sample Science Notebook Pages* for students to observe individually.

4. Have students brainstorm a list of similarities and differences among the three notebook samples. Discuss why they might have similarities.

5. Remind the class how they have videos from The Father of Fast Plants, Paul Williams, and one is about his science notebook. Show the video.

- After the video, pose the question: How does Paul Williams' science notebook help him do his scientific work?

6. As a class, reflect back on the brainstorm list about similarities among the science notebooks, and compare that list to what Paul Williams said in the video to look for similarities that could be the start of class criteria for notebook entries.

7. Remind the class that they are working like scientists to answer the question, ***How fast are Fast Plants?*** and explain how they will benefit from having an agreed upon criteria for notebook entries so that entries are similar enough to make sharing observations and evidence more effective.

- Hold a discussion to add to the brainstorm list everything the class can think of that is important to include in a science notebook.

(continued on following page)

- As appropriate, refine the class list to the most important factors to include, and have students further explain how each factor will look if it is done well.

8. Have each student begin a notebook, and tape the note cards and observations from previous lessons into the book.

- Add dates as appropriate and place entries in chronological order.

9. Have students make Fast Plant observations, and record them in their science notebooks using the class-established criteria for entries.

10. Use the REAPS questions throughout the lesson where appropriate.

REAPS Questions

R **Draw in your notebook how your seeds have changed since you placed them on the paper towel to germinate.** Look for students to be able to accurately represent both growth and development of a Fast Plant from seed.

E **Compare a seed to a flowering plant. How are they related?** The seed is the offspring or baby of the fully-grown plant.

A **Explain how a TV guide or artist's sketchbook is similar to a science notebook. How are they different?** A TV guide, like a science notebook, gives specific times when things happen, includes short descriptions, and organizes information so that it is easy to retrieve. An artist's sketchbook is a record of ideas and work that is usually organized so the artist knows when sketches were made, and it may include labels and/or short descriptions. A TV guide does not document the study of natural phenomenon, and an artist can record anything he or she imagines; it does not focus on evidence.

P **Predict if you will see more variations or differences in the speed of growth when Fast Plants are in planting mix or in a Petri dish. Explain your prediction.** Look for recognition by students that there are probably more variables in the potting mix environment that might affect the rate of germination (depth of planting, amount of water, how hard the mix was packed, etc.).

S **What will be most difficult about keeping a science notebook that meets the criteria we established in class today? What strategies do you think might help you with that?** Help students recognize that a systematic approach—always taking out the science notebook at the start of class and recording notes neatly and with organization are two key strategies for using this tool well.

Teacher Background Information

What are Science Notebooks?

One way that scientists keep a record of their observations, data, explanations, and ideas is by recording them in a notebook. Using science notebooks is a standard practice in all science disciplines. Whether in a university, government, or private industry research laboratory or in the field, scientists use notebooks to record their questions, observations, data, explanations, and predictions about whatever phenomenon they are studying. These notebooks are then used to compare new and old data; formulate explanations, models, or theories; and develop presentations to communicate results to others.

Using Science Notebooks

Research on how people learn and the use of science notebooks in the classroom provides good reasons for using science notebooks in the classroom. These include substantial improvements in student learning and writing skills. They also provide students with an organizing tool for the unit and are a valuable source of feedback for teachers about students' understandings.

The use of science notebooks for each student is strongly encouraged for all science lessons, particularly those throughout this unit. Specific opportunities for using science notebooks in this unit are explicitly described where appropriate. A bound notebook works well for a science notebook because its pages cannot easily be torn out or replaced, handouts and other loose pieces of paper can easily be taped in, and it is inexpensive.

Key features for science notebook entries that other teachers recommend to both help the learner stay organized and make reading/assessing student-notebooks manageable include:

- student's name on the outside cover of the notebook—all student's names in the same location so it is easy to locate any one notebook in a stack
- a title for each new entry (you may want to have students begin a new page for each new lesson and/or use a highlighter to highlight the titles where new lessons begin to make navigation easier)
- the date (placed in an agreed upon location, such as the left hand margin, so it is easy to find)
- captions and/or titles for observations—drawings, written descriptions, tables with data
- location (if not in the classroom)
- written responses to all REAPS questions assigned to be recorded
- class notes from discussions and mini-lectures
- all mathematical computations (not just the answers)
- partners' names when working in small groups

Additional items:

- empty space to write additional notes later (in some cases teachers use a strategy in which one type of record is kept on the right page and a different type of record, such as notes taken during class, are kept on the left page)
- environmental/weather conditions
- specific types of descriptive words
- units of measure and/or references about relative size
- drawings that are accurate representations with colors and labels

There is additional information about using science notebooks in the ***Immersion Unit Toolbox***.

Advance Preparation

This lesson includes a video segment featuring Paul Williams talking about keeping a science notebook; plan in advance, how you will project this for your class (computer/projector, TV/player). Also, make a sufficient number of copies of *Student Page 1.3A Sample Science Notebook Pages* for your class.

Implementation Guide

1. Explain to students that in this lesson the class will explore how scientists use scientific notebooks, focusing on the question, **Why is a science notebook such an important tool that nearly every scientist uses one?**

Share with the class that because in this unit students work like scientists, they will need to keep science notebooks, too. At this time you could mention how observations up until now haven't been as well organized as they would be if they were in a science notebook.

2. Use a Think-Pair-Share strategy to help students reflect on their previous experiences keeping notebooks for science.

- Have students individually write three things that are important to include in a science notebook.

3. Explain that one way to learn more about what is important to include in a high quality science notebook is to look at examples from successful scientists. Distribute Student Page 1.3A *Sample Science Notebook Pages* to each student, and instruct students to spend a few minutes looking at the notebook pages. There are examples from Jane Goodall's observations during her early studies, a page from Paul William's notebook, and a page from an entomologist's field notebook, studying insects. Encourage students to imagine what each scientist was looking at when he or she wrote the entries.

4. Organize students in groups of four and have them brainstorm a list of similarities and differences between the scientists' notebook pages. Have one volunteer from each group share with the class their observations about similarities and differences among the notebooks. Encourage questions and speculations from students about why scientists keep their records the way they do.

Guide the discussion to draw students' attention to two science notebook features:

- There is more than one way for scientists to organize their science notebooks and record their observations.
- Entries include dates, observations, comments, and other basic kinds of information that provide both context and detail.

5. Let students know that you also have information on video about how Paul Williams uses his science notebook. After viewing the video, pose the question:

- How does the way Paul Williams' organizes the information in his science notebook help him do his scientific work?

6. As a class, reflect back on the brainstorm list about similarities among the science notebook pages, and compare that list to what Paul Williams said in the video to start a discussion about the class's criteria for notebook entries.

Point out to students that, even though the three scientists were investigating gathering very different data, they all recorded their observations and comments regularly and organized their notebooks so that it is easy to read and useful.

7. Bring students back to thinking about what their own science notebooks will look like. Explain that as a class you will work together to describe the criteria for what makes a good science notebook and then use that criteria. Point out how having the same criteria for making science notebooks will make it easier for students to communicate with one another and you by sharing observations and evidence.

- Hold a discussion to add to the brainstorm list everything the class can think of that is important to include in a science notebook.
- As appropriate, refine the class list to the most important factors to include, and have students further explain how each factor needs to be completed for highest quality.

If necessary, provide some guidance by asking questions such as:

- What kinds of entries will we make in a science notebook?
- What needs to be in each entry?
- What would make our science notebooks useable for us? For others?

Possible criteria include:

For investigations:

- name of the investigation
- procedure for investigation
- observations and measurements
- comments about observations, thoughts, the process
- how measurements are taken each time
- when entries are made (day, month, year, and time)
- where investigation is performed

General criteria:

- new lesson or project always starts on a new page
- entries are readable
- entries are objective observations, unless specified as thoughts and speculations, opinions.
- use a pen (or pencil) and draw line through changes instead of erasing or crossing them out.
- organized
- calculations included
- explanations include reasoning

8. Explain to students that they will now begin their own science notebooks using the criteria the class established. Have students start their notebooks by taping the notes and note cards they collected in the first two lessons.

- Add dates as appropriate and place entries in chronological order.

NOTE: Save the class-generated criteria for science notebook entries. Before the next lesson, use this list to revise the rubric provided on the Unit CD so that it reflects your class criteria to use in the science notebook peer review (and future assessments you conduct).

9. Have students make Fast Plant observations, and record them in their science notebooks using the class-established criteria for entries. What students include in the science notebooks and how they include it will provide valuable information that can be used to assess student understanding.

Travel around the room and reinforce students who are following the criteria carefully and in detail. Clarify any criteria established by the class that seem to be challenging for students as they set up their notebooks.

10. Use the REAPS questions throughout the lesson where appropriate.

Student Page 1.3A: Sample Science Notebook Pages

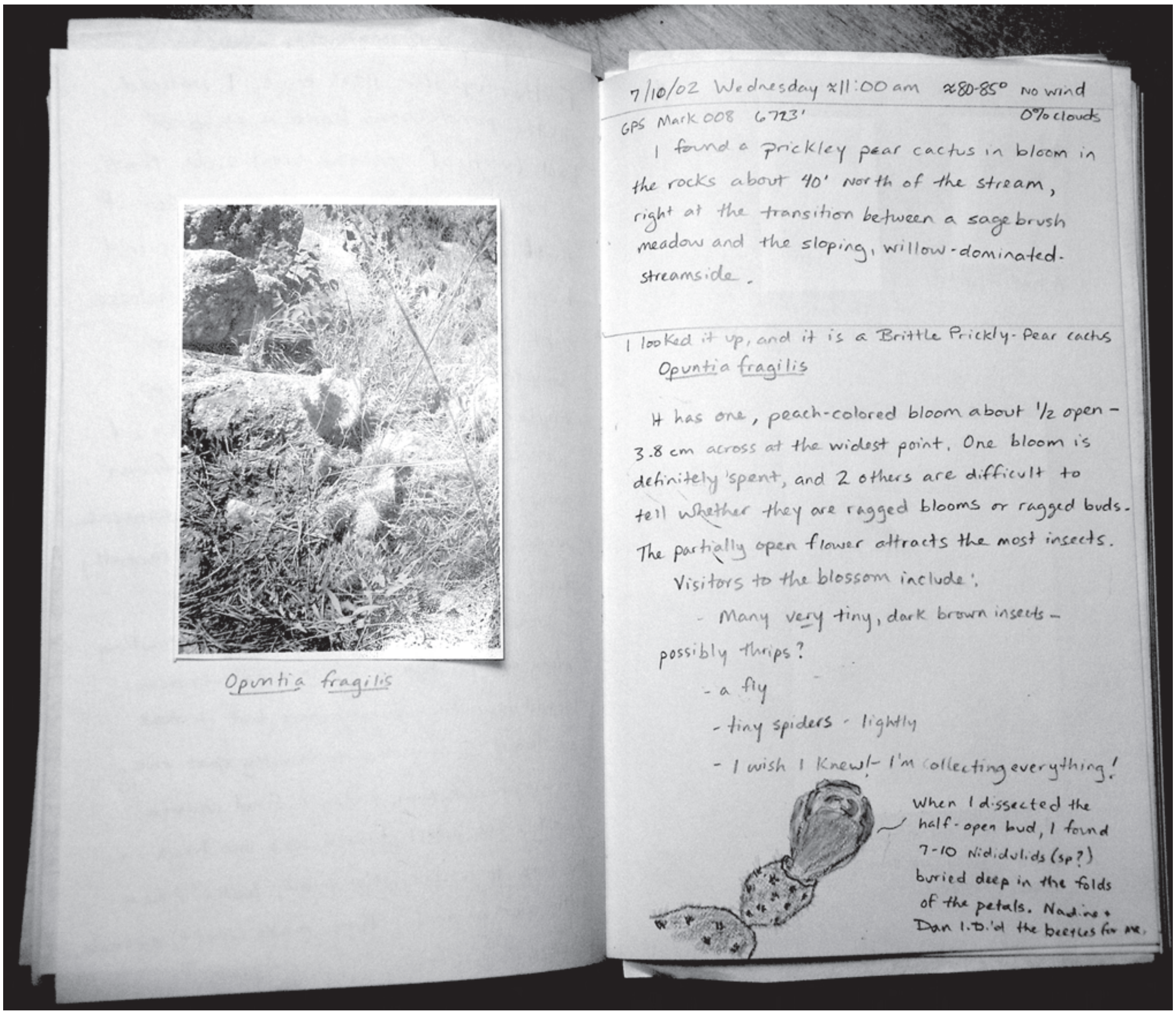


Table 1: 3/2/00 PHW

Fast Plants Growth, Development & Reproduction

Your name: PHW Date of sowing 5/28/00

Plant Variety: Rbr, C1-33, LUT96

Standard environment: PLHi#, FCS, 150 μM, PAR

Variable environment: 1/8 x Peters nutrient

Plant #	Plant Trait Measured					
	height (mm) 18 das	# of leaves on stem	# hair, 1st leaf margin	# flowers pollinated	# seeds	other
1	262	6	22	29		
2	279	6	56	15		
3	253	5	0	13		
4	242	7	1	17		
5	301	7	6	21		
6	311	6	0	16		
7	267	7	18	25		
8	302	5	21	22		
9	254	7	16	21		
10	264	6	26	20		
11	230	6	26	12		
12	315	7	31	21		
n	12	12	12	12		
$\bar{x}$	273	6.3	19	19		
s	28	0.8	16	5.0		
r	65	2	56	17		

n = number of plants measured

x = average measure = sum of measures ÷ n

r = range of variation = highest - lowest value

(option) s = standard deviation, = average variation around the average, x. (use statistical calculator)

Fifi.

4 June (14) 292 Then ff reach to Ft again. Stops and —.
Takes Ft's hand. Grm Fg. Later pulls his foot.
Pulls him quite away. Flo looks.
ff sits up & puts arms round him. Ft push up
& nearly looks over ff sh. Flo lifts him away (1')

4 293 ff (later) waves his arm round. lips & his imp.
ff grm Flo. Pulls at Ft.

4 294 ff touch Ft. Flo push ff head > foot (both lying)
298 Pulls him away for moment only. Flo pulls back. 9.15
Pulls his foot - DD on it.
ff reaches to him. Ft sleeps. Flo push ff

5 301 ff pulls him away. Holds on lap. St-whimp. Flo pulls him back.
Ft then seems to reach to ff. Grabs leaf > one x.
ff picks twig of leaf, & pulls both his x & his.
Flo pulls him back. Flo → ff.
Next ff kicks Ft > heel.
Goes up to play > Ft. Flo twice gathers him as ff rough, & Ft whimp. He whimps as ff DD foot.
Ft crawls up ff. ff held. He whimps.
Flo takes back.
ff DD 3 more times.
ff takes Ft away. Ft after mo crawls back up Flo.
ff grabs his x > play face. Then → Flo.
Touch Ft again. → Fg.

302 ff grabs leg & waves (Ft has ant on lip)
ff takes. Ft whimp & creep tow Flo who grabs
1st x then chest as ff keeps hold. ~~ff lets go~~.
Flo lets go. Ft hangs out Flo ff lets go.
Holds foot. ff → ff.

303 ff pl. Ft. Flo push > foot.

304 ff pulls under arms & gets Ft away. As she holds
Ft Flo → ff. Then after 1½' Flo removes. (4.30)
Then → ff again.
ff pulls his chin. He whimps. Flo takes back (4.43)
ff plays > Ft.
ff pulls at & pats Ft. Turns away from Flo > him.
Fg appr. ff bip. Goes first of trip & then
quad > Flint chirping & down. Flo foll.
calmly. ff has him 3'

5 305. ff tries twice to take Ft. Then gets. Rolls 3 feet
from Flo & sits by Fg. Flo gives her 'hoo'
sounds (6) Reaches & takes Ft back.
Twice ff grabs such Ft - Flo pores.
Then ff follows. Gets Ft. Rolls out back. Sits up
& nuzzles. (Back & Flo) 'Bounces' him on his legs.
He stretch arms to Flo. Flo reach for
him - ff hangs on & dd.
ff can't to pull. He pants. Whimp. Flo ~~det~~ad >>
ff x. Turns from ff. ff ont & nuzzle his
head. Pulls. Bites hand. Jerks arm up & down.

(37)

Science Notebooks: Peer Review

Key Concepts

- Clear communication and accurate record keeping is an essential part of doing science
- Results of scientific investigations are seldom exactly the same, but if the differences are large, it is important to try to figure out why.

Evidence of Student Understanding

The student will be able to:

- evaluate a peer's science notebook entries using the class criteria effectively.

Time Needed

50 minutes

Materials

For each group of 4 students

- their 1 quad of growing Fast Plants
- their Petri dish with growing Fast Plants

For each student

- science notebook
- 1 copy of Student Page 1.4A *Science Notebook Rubric*

1. Explain to students that if everyone is doing a good job with their science notebooks they will be able to trade notebooks and understand the entries. Pose two questions to the class and discuss briefly,

- **What is probably the easiest part of your science notebook for someone else to read and understand?**
- **What is probably the most difficult part of your science notebook for someone else to read and understand?**

2. Distribute and explain Student Page 1.4A *Science Notebook Rubric* to remind students about the class expectations for science notebook entries.

(continued on following page)

REAPS Questions

R **What is one reason for scientists to create science notebooks that others can read and understand?** There are many reasons including, so others can repeat your investigation and check the accuracy, so others can understand your thinking process and the evidence you based your explanations on.

E **What evidence would you have to demonstrate that you have done a good job on your science notebook?** Other students would be able to read and understand the entries.

A **How can you tell if others will be able to understand what you did when they read your science notebook?** Students can apply the Science Notebook Evaluation Rubric to determine how easy it is for others to understand entries in your notebook.

P **Predict: Which features of science notebook entries are the most difficult things for others to understand?** Predictions will vary. The important part of student predictions is the logic that students use to make their predictions.

S **After receiving feedback from others about your science notebook, how have you made it stronger?**

3. Explain that after the observations today are recorded, classmates will exchange notebooks as you direct and read entries to give feedback about improving how they are written.

4. Have students make Fast Plant observations, and record them in their science notebooks using the class-established criteria for entries.

5. Direct students to exchange notebooks according to your plan.

- Have students apply the notebook entry rubric on the number of entries determined in advance. Travel around the room as students review notebooks, and assist with applying the rubric and giving feedback.
- Use this as an opportunity to informally assess students' work.
- Provide time for the reviewers to give feedback to the science notebook authors.
- Allow students additional time to make improvements before collecting the notebooks yourself to read and assess.

6. Use the REAPS questions throughout the lesson where appropriate.

Teacher Background Information

This lesson features a peer review to help students improve the quality of their science notebooks. Teachers using science notebooks often report that students respond particularly well to knowing that their peers will be trying to understand what they record in their notebooks. In addition, the experience of trying to understand someone else's notebook entries can clarify for students the amount of detail and organization that is necessary to include in their own entries.

This peer evaluation is intended only to be used as an informal assessment. Do not have students assign grades; it defeats the purpose of the lesson to provide informal feedback. One goal for having students engage in the thoughtful development of criteria and a common approach to keeping science notebooks is to encourage collaboration in a way similar to how scientists work together.

Advance Preparation

NOTE: Before this lesson, use the class's criteria for science notebook entries to revise the rubric provided on the Unit CD so that it reflects your class criteria to use in the science notebook peer review (and future assessments you conduct). A Word file for the rubric is available on the Unit's CD to be customized for your class.

Decide in advance on a strategy for having students exchange science notebooks. Rather than having students choose whom to trade with, it is suggested that you make the exchange more random and consider having students generally be seated away from each other so that the notebook must speak for itself (not have its author nearby to interpret).

One method for exchange is to walk a path through your classroom collecting all the notebooks into a stack in your arms, then repeat the same path handing out notebooks so that the last one collected is the first one handed out. If you use this technique, keep in mind that near the middle of the path you will need to either shuffle the notebooks a little or change your path slightly so that students don't receive either their own or a near-neighbor's notebook.

Implementation Guide

1. Invite students to imagine that years from now, a scientist will find their Fast Plant science notebooks. Ask the class, could someone figure out what you did in your investigation, just by reading your science notebook?

Explain that students don't need to wait for years to see if someone else can understand their science notebook entries. If they are doing a good job with their science notebooks, they will be able to trade notebooks with someone else and understand each other's entries. Ask students to reflect on what it would be like for someone else to read the notebook entries they made the previous day. Discuss the following questions briefly:

- What is probably the easiest part of your science notebook for someone else to read and understand?
- What is probably the most difficult part of your science notebook for someone else to read and understand?

Emphasize that one of the main goals in keeping a science notebook is to document your work so that others can evaluate and even try to duplicate it if needed. In addition, it is important that students communicate sufficiently with their teacher what they are doing and learning so that it can be accurately assessed (and sometimes graded).

2. Explain to students that later in this lesson they will use a rubric to evaluate each other's notebooks for giving feedback to help improve entries. Distribute and explain Student Page 1.4A *Science Notebook Rubric* to remind students about the class expectations for science notebook entries (discussed and outlined in Lesson 3).

Provide an overview of the work to be completed today. In this lesson, students will do three things:

a. record their observations of Fast Plants in their science notebooks.
b. exchange notebooks with a classmate according to directions.
c. read each other's notebook entries and give feedback about how the entries can be improved.

Be sure that students understand that the goal of the notebook exchange is for students to help each other improve their notebook entries. Do not have students *grade* their peers' notebooks.

4. Have students make their daily observations of Fast Plants and record observations in their science notebooks according to the criteria discussed and established in class during Lesson 2.

5. Direct students to exchange notebooks according to the process decided upon before class. Explain to students that when looking at their neighbor's notebook, they will:

- evaluate how well the entries meet the criteria for good science notebook entries.
- make recommendations for how entries can be improved.

Have students apply the notebook entry rubric to today and yesterday's science notebook entries. Explain how a rubric can be used to point out where improvements can be made.

- Have students give feedback to each other by using a highlighter to highlight descriptions on the rubric that align with the quality of work shown in the science notebook being reviewed. In addition, feedback can be given by writing comments on the rubric.
- Travel around the room as students review notebooks, and assist students with applying the rubric and giving feedback.
- Use this as an opportunity to informally assess students' work.

When students finish their peer evaluations, have students return the notebooks to their owners. Then allow the notebook authors additional time to revise their notebook organization before the notebooks are collected for teachers to review.

6. Use the REAPS questions throughout the lesson where appropriate.

Student Page 1.4A: Science Notebook Rubric

Performance Criteria	Attribute	Exemplary 5	Learning 3	Beginner 1
The science notebook is organized and includes the headings, labels and dates that reader needs to follow. • *Name of investigation on each page* • *Dates next to each entry or group of entries* • *New lessons and projects start at the top of a page* • *Entries are in the order observations or comments were made (chronological order)*	Breadth Completeness	Science notebook is well organized. Includes headings, dates, and labeling needed to follow organization of notebook; it is easy for the reader to open the notebook to any page and figure out what was done.	Science notebook shows some features of being well organized. Is missing some of the headings, dates, and labeling that is needed for reader to fully understand what was done.	Science notebook not organized. Does not include all of the headings, dates, and labeling needed to be organized so that it is difficult or not possible for a reader to understand what was done.
Entries in the science notebook are accurate. • *Author makes clear which entries are observations and which are comments or thoughts of author* • *Measurements are in appropriate units* • *Measurements are reasonable and/or explained* • *Statements are accurate: not overstated*	Accuracy	Notebook entries are accurate and use appropriate units Measurements are reasonable or explanations are suggested for unusual data Statements are accurate/ not overstated	Notebook entries are complete and generally accurate and include units Measurements are reasonable Statements are brief but accurate/ not overstated	Notebook entries are incomplete or not accurate, may incorrectly use or not include units Measurements are not reasonable or insufficient for the task Statements are overly brief or not accurate or reasonable
The science notebook communicates information clearly. • entries are readable and make sense • handwriting is easy to read	Clarity	Information in the notebook is extremely clear in at least 90% of the entries	Information in the notebook is clear in substantially more than 50% of the entries	Information in the notebook is not communicated clearly in 50% or more of the entries

Rubric format based on rubric design by Tierney, Robin & Marielle Simon (2004). What's still wrong with rubrics: focusing on the consistency of performance criteria across scale levels. *Practical Assessment, Research & Evaluation*, 9(2). Retrieved May 13, 2006 from *http://PAREonline.net/getvn.asp?v=9&n=2*

Scientific Explanation: How Fast are Fast Plants?

Key Concept

- Communicate the logical connection among hypotheses, science concepts, tests conducted, data collected, and conclusions drawn from the scientific evidence.
- Seeds are the structure from which flowering plants produce new plants.

Evidence of Student Understanding

The student will be able to:

- develop an explanation for how fast Fast Plants are, based on experimental observations and evidence from a written resource.
- reflect on their own learning and accuracy of their original prediction in light of evidence.
- draw a diagram showing how new plants emerge from seeds.

Time Needed

80–100 minutes

Materials

For each student

- 1 copy of Student Page 1.5A *How Fast are Fast Plants compared with Other Plants*
- 1 copy of Student Page 1.5B *The Development of Fast Plants*

For the class

- 2 transparencies of Teacher Page 1.5A *Fast Plant Data*

1. Take 5–10 minutes before starting this lesson for students to conduct their daily observations and record notebook entries on Fast Plants.

2. Explain to students that they are working like scientists by deciding how to analyze how fast Fast Plants are. At this point, they have conducted an entire investigation to answer the question about how fast these plants are.

3. Remind students that the original question they asked before planting their plants was "**How Fast are Fast Plants?**" Ask students to explain their current ideas about how to respond to this question. Record students' responses on the board.

- Be sure that students include evidence for their ideas.
- Instruct students to identify if they are describing individual plants or a population.
  - NOTE: Several plants in the same quad or all the quads on the same water reservoir are considered a population.

4. Conduct a whole class discussion to define what the question "How Fast are Fast Plants?" means. Instruct students to:

- Make a list of possible criteria for what fast could mean.

5. Explain to students that, as a class, they will develop an explanation for how fast Fast Plants are according to two sets of criteria:

- when the first plant FIRST appears above the soil surface.
- a second set of criteria selected by the class

Guide students to work together as a class to select the second criteria from their list of possible criteria.

6. Have students work in pairs to review their own records to see if they have the evidence they need to describe when their Fast Plants first emerged above ground. They will need to calculate how many days based on the date they planted the Fast Plants and the date they emerged.

- Record the number of days it took each plant to emerge from each team on a transparency of Teacher Page 1.5A *Fast Plant Data—Days to Emerge*

(continued on following page)

- Ask students to look for patterns in the class data.

7. Use a Think-Pair-Share strategy to find out how students would calculate **the mean number of days until the class's plants emerged from the soil**.

8. Repeat sections 6 and 7 with the second criteria the class chose to determine how fast Fast Plants are.

9. Introduce students to Student Page 1.5A *How Fast are Fast Plants Compared with Other Plants*.

- Have individual students add Fast Plants to the graph.
- Invite students to describe how fast the Fast Plants are compared to other plants.

10. An article, Student Page 1.5B *The Development of Fast Plants*, provides information from Paul Williams about his work developing and analyzing data about how fast Fast Plants are, and that can be used as additional evidence.

- After students read *The Development of Fast Plants*, hold a whole-class discussion to see how evidence from that article could be used to strengthen their explanation.

11. Have students reflect back on their original predictions for how fast they thought Fast Plants would be and explain how it compares to what they now know.

- Highlight how scientists revisit their original predictions throughout their investigations.
- Direct students to review the *Unit Level Graphic Organizer* and contribute new concepts they learned by conducting this investigation.

12. Use the REAPS questions throughout the lesson where appropriate.

REAPS Questions

R **Draw and label a diagram showing what happens when a flowering plant makes seeds and its seeds are planted.** This drawing ought to show understanding that a flower produces seeds and a new plant emerges from a seed.

E **Looking at your team's plants, explain if they look like all their needs were met or not. If not, what do you need to do differently to meet their needs when you grow Fast Plants again?** Answers will vary. Use this question to help students recognize if they planted correctly and tended their emerging plants well (right number of seeds, good depth of soil, plenty of moisture throughout, thinned to one plant/cell etc.).

A **Why is it useful to calculate the mean number of days until the class's plants emerged from the soil?** The mean is more valuable to know when analyzing traits in a *population*.

P **Give at least three examples of other types of plants you might expect scientists to be working with to develop faster growing types. Explain your list.** Work to breed trees that grow quickly for shade or wind protection, grasses that grow quickly to cover disturbed ground, all kinds of fruits and vegetables to produce early crops, and flowers that grow quickly to provide early blooms are all examples.

S **Look at the first note card you wrote in Lesson 1, and compare your response to the question, *How can a scientist "develop" a new type of plant like a "Fast Plant?"* to your current understanding of how a scientist like Paul Williams can do this. How has your thinking changed so far?** At this point, students need to be developing an understanding of the idea that variation in plants can be influenced by the environment and selected for by a plant breeder (or nature).

Advance Preparation

Lesson 1.5 is particularly important for setting the expectations in this unit and in your class for evidence-based explanations. It is important that students experience in this lesson how to decide what evidence is important, analyze experimental results for patterns, and use logic and reasoning to develop an explanation for those results. Additional resources for preparing to teach these inquiry skills and abilities to students can be found in the *Immersion Unit Toolbox*.

Implementation Guide

1. Have students conduct their daily observations of Fast Plants and make notebook entries before the lesson.

2. Explain to students that they are working like scientists by deciding how to analyze how fast Fast Plants are. At this point, they have conducted an entire investigation to answer the question about how fast these plants are.

3. Remind students that the original question they asked before planting their plants was "How Fast are Fast Plants?" Ask students to explain their current ideas about how to respond to this question. Record students' responses on the board.

- Be sure that students include evidence for their ideas. Consider asking questions like "What makes you say that?" and "How do you know that?" when a student makes a claim without sharing the evidence that supports their claim. Also, encourage students to question each other about the evidence on which they are basing their claims.
- Use this opportunity to have students start recognizing when they are describing individual plants or a population. Throughout this unit, students will need to distinguish when they are talking about individuals and when they are talking about populations.

4. Ask students if they think the question, "How Fast are Fast Plants?" is a scientific investigation question. Prompt them to recognize that the question does not make it clear what is meant by fast. Point out that scientists are extremely careful to write questions that clearly indicate what they are asking. Ask the class to work together to define what the question "How Fast are Fast Plants?" really means. To guide this discussion, suggest making a list of criteria that would help explain what they mean by fast. For example,

Does fast refer to the number of days until the plant:

- grows the first root?
- develops the first flower?
- first cotyledon opens?
- germinates?
- breaks through the soil?
- flowers?

5. Explain to students that, as a class, they will develop an explanation for how fast Fast Plants are according to two sets of criteria:

- when the plants first appear above the soil surface
- a second criterion that class selects from their list

Guide students to work together as a class to select the second criterion from their list of possible criteria (the list that was generated by the class in #4). Explain that the class will use these two pieces of evidence to begin to explain just how fast Fast Plants really are.

6. Have students work in pairs to review their own records to see if they have the evidence they need to describe when their Fast Plants first emerged above ground. They will need to calculate how many days based on the date they planted the Fast Plants and the date they emerged.

- Next, have one student from each quad group share the number of days it took for each of their Fast Plants to emerge from the soil. Allow other group members to agree or disagree with the calculation.
- Once the team has agreed upon the correct number of days for each plant, record the number of days for each of their plants on a transparency of Teacher Page 1.5A *Fast Plant Data.* In the blank at the bottom of the Teacher Page, record "emerged from the soil" and title the graph appropriately.

- Explain that whenever scientists have data one of the first things they do with the data is begin to look for patterns, and since they are developing a scientific explanation for just how fast Fast Plants are, looking for patterns is a logical next step. Prompt students to study the patterns with questions like:
  - Do all Fast Plants emerge after the same number of days?
  - Do you see any patterns in the differences in the data among groups?
  - Does any data seem to be extremely different from the rest of the data?

7. Explain to students that scientists that work with lots of data (like their graph displays) often use math to summarize the data. This is especially useful when they are talking about populations, instead of individuals. Share that instead of trying to talk about the number of days that each plant took to germinate, the class can summarize the data by calculating the mean number of days that the class's Fast Plants take to emerge from the soil. Use Think-Pair-Share for students to calculate the mean number of days until the class's plants emerged from the soil.

- Have students first individually think about how they would go about calculating the mean, and then individually calculate the mean.
- Then, allow students to work in pairs to discuss how they calculated the mean and compare their answers.
- Conduct a class discussion to formalize the correct way to calculate a mean.
- Determine the correct mean number of days that the class's Fast Plants took to emerge from the soil.

8. Repeat sections 6 and 7 with the second criteria the class chose to determine how fast Fast Plants are. Students will need to review their science notebook records to calculate the number of days each plant took to reach the criteria and then provide data for the second transparency of Teacher Page 1.5A *Fast Plant Data*. In the blank at the bottom of the Teacher Page, record the criteria and title the graph appropriately. Finally, they will need to calculate the mean number of days for the class's Fast Plants for that criterion.

NOTE: *If students decide the second criterion ought to be number of days to flowering or some other factor that has not yet occurred, repeating sections 6 and 7 can be delayed until after the data is collected.*

9. Explain to students that based on these two lines of evidence they have developed an initial idea for explaining how fast Fast Plants are. Remind students that evidence is key to making a strong scientific explanation. Explain that you have another piece of evidence that might help them with their explanation about how fast Fast Plants are. Introduce students to Student Page 1.5A *How Fast are Fast Plants Compared with Other Plants*.

- Have individual students add Fast Plants to the graph, which shows the number of days different plants take to emerge.
- Invite students to describe to their neighbor how fast the Fast Plants emerge compared to how fast the four other plants emerge.

10. Explain that since they now have three solid pieces of evidence to help them explain how fast Fast Plants are, there explanation is stronger. Describe that when scientists are developing explanations they often turn to the work of other scientists to see how it fits with their own explanation.

Share that you have an article about the work of a scientist, Student Page 1.5B *The Development of Fast Plants* that the class can use as additional evidence. It provides information from Paul Williams about his work developing and analyzing data about how fast Fast Plants are.

- Use an appropriate reading strategy for your students to understand the story.

After students read *The Development of Fast Plants*, discuss the story, and emphasize the points in the story that define, explain, or refer to the following key concepts:

- Flowering plants reproduce by developing seeds, which develop into new plants.
- Reproductive success is defined by the number of offspring that a parent produces. **Note**: *To truly be successful the offspring must be able to reproduce and continue to pass down the parents' genetic code*.
- Selection is a process (natural or artificial) in which some plants are allowed to survive and reproduce based on their traits.
- Environmental stresses are conditions that challenge the health and well-being of individuals living in the environment with those conditions.

Next, guide the discussion to use all the evidence that the class has gathered (from the reading as well as the experiment) to develop a well-formed logical explanation for how fast Fast Plants are.

- Remind students that they will be developing explanations that use this same type of structure when they conduct their own experiments in the next weeks.

11. Have students reflect back on their original predictions for how fast they thought Fast Plants would be and explain how it compares to what they now know.

- Highlight how scientists revisit their original predictions throughout their investigations.
- Direct students to review the *Unit Level Graphic Organizer* and contribute new concepts they learned by conducting this investigation.

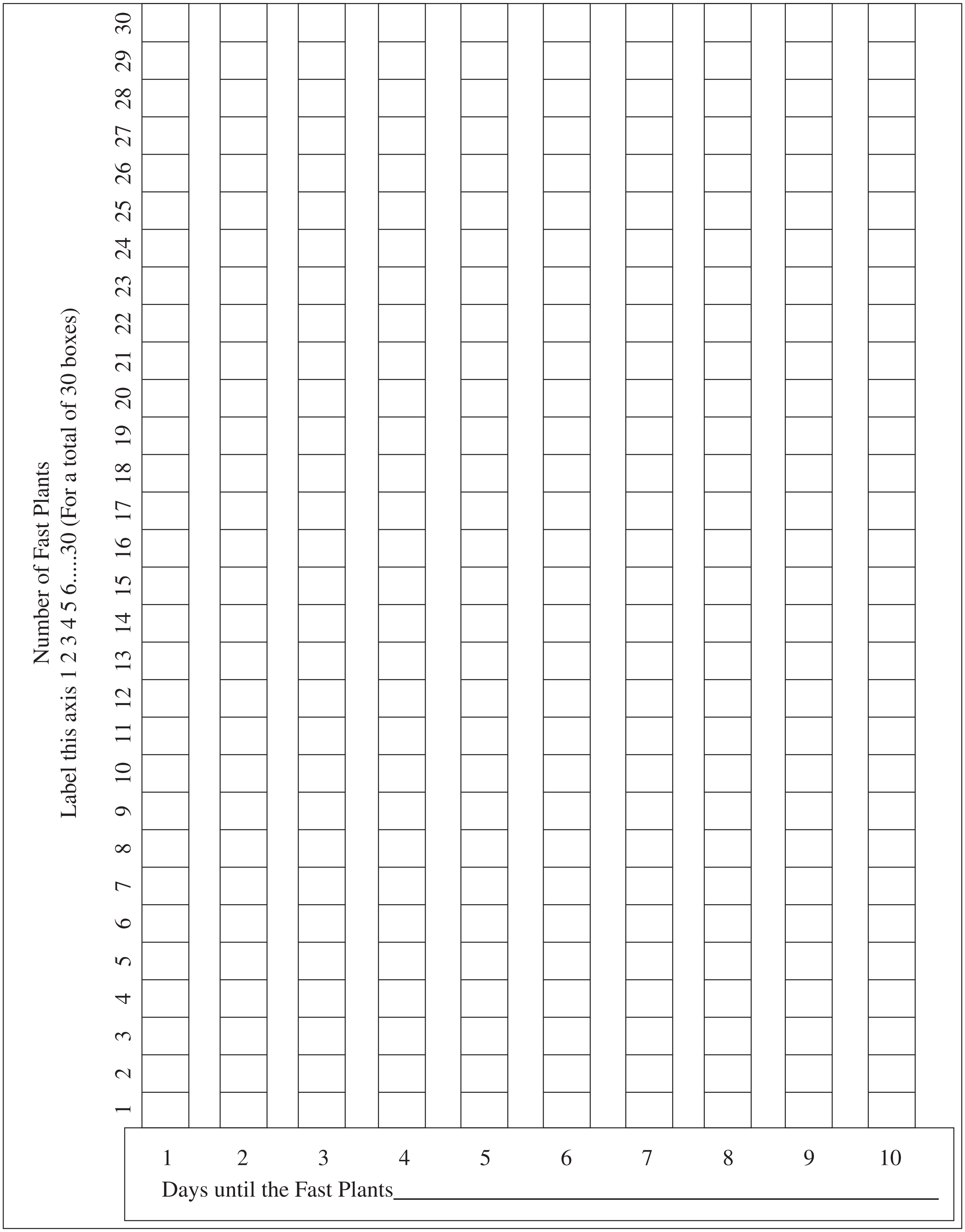
A sample entry for the Graphic Organizer is shown below.

12. Use the REAPS questions throughout the lesson where appropriate. The **S**elf reflection question asks students to compare their response to one of the first questions asked in Lesson 1, How can a scientist "develop" a new type of plant like a "Fast Plant?" to their current understanding.

- At this point, students need to be developing an understanding of the idea that variation in plants can be influenced by the environment and selected for by a plant breeder (or nature).

What we did	What we know	How we know it
Grew Fast Plants from seed and recorded observations to determine how "fast" they are. Analyzed our observations and measurements from growing Fast Plants.	Fast plants emerge from their seeds and grow more quickly than most plants.	• We have data from the class experiment. • We calculated the mean for the number of days to emergence in our class. • We read in the article how many days to emergence Paul reports that Fast Plants take.

Teacher Page 1.5a: Fast Plant Data



Student Page 1.5A: How Fast are Fast Plants Compared with Other Plants?

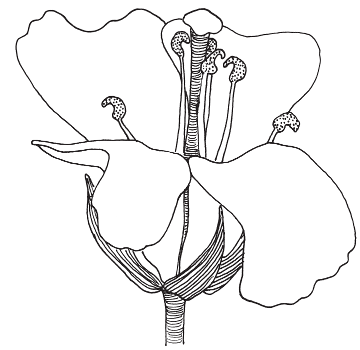
Type of Plant	Number of Days Until the Seedling Emerges From the Soil
Sunflower 	10 – 14 days
Cherry Tree 	7–21 days
Corn 	5–7 days
Peppers 	10–12 days
Fast Plants 	

Student Page 1.5B: The Development of Fast Plants

The story of the Fast Plants begins many many years ago in the kingdom of Nepal. High up on a rugged mountainside of the Himalayas, a farmer walked out to check his newly planted field of barley.

It was late in the spring. The snow had recently melted and the ground was becoming warm again. The barley grass he had planted a week ago would grow and provide grain for cereal, and for the fried bread that he liked to eat. The farmer was intending to just check the field, as farmers do. He didn't expect to see any plants yet.

Imagine his surprise when he spotted patches of weedy looking *Brassica* plants, growing sturdily in the early spring sunlight. These weeds must have sprouted very fast. The farmer thought for a bit. It had been a long winter and a long time since his family had had any fresh vegetables to eat. It would also be three months before the barley he had just planted could be harvested. So instead of pulling up the weedy plants and throwing them away, he took some home for a salad for the family's supper.



Brassica FLOWER

In a few days, the farmer went back to his field. By this time, the little plants were flowering. The bright yellow flowers looked like sunshine on the mountainside. Each time he visited the field, the farmer took a few plants home for his family to eat. The remaining plants attracted many hungry honeybees. The honeybees spread pollen from one flower to the next, and that is how flowering plants reproduce. Soon the bright yellow flowers produced pods with plump seeds. The farmer and his wife pressed some of the seeds for oil that they could use in cooking. The farmer wisely kept the rest of the seeds to plant the following year. He knew that new plants come from seeds.

The next spring he scattered his field with two kinds of seeds, the *Brassicas* and the barley. Both of the crops grew fairly quickly, but the weedy *Brassica* plants came up first and were already flowering while the barley was still spreading its shoots across the ground. These little plants had high ***reproductive success*** because they produced many healthy offspring. The farmer harvested the *Brassicas* before the barley was tall enough to shade them from the sun. He was able to produce two crops on one piece of land, providing enough food for his family, and for the farm animals, the yaks.

Year after year, the farmer saved and replanted some of the *Brassica* seeds. The little weedy *Brassica* was an easy plant to grow, and required no special fertilizer. It was well-adapted to survive there on the mountainside.

Time passed. Soon, the farmer's grandchildren were farming the same crops on the terraced mountain field. And so it continued, generation after generation.

One day early in the twentieth century an American plant explorer visited the mountainside farm in Nepal. When she saw the field of weedy little plants, she recognized them as a kind of *Brassica*. She knew about the family of plants called *Brassicas*. Many common vegetables such as broccoli and cabbage are members of this family. Other *Brassicas* are mustard and canola oil plants.

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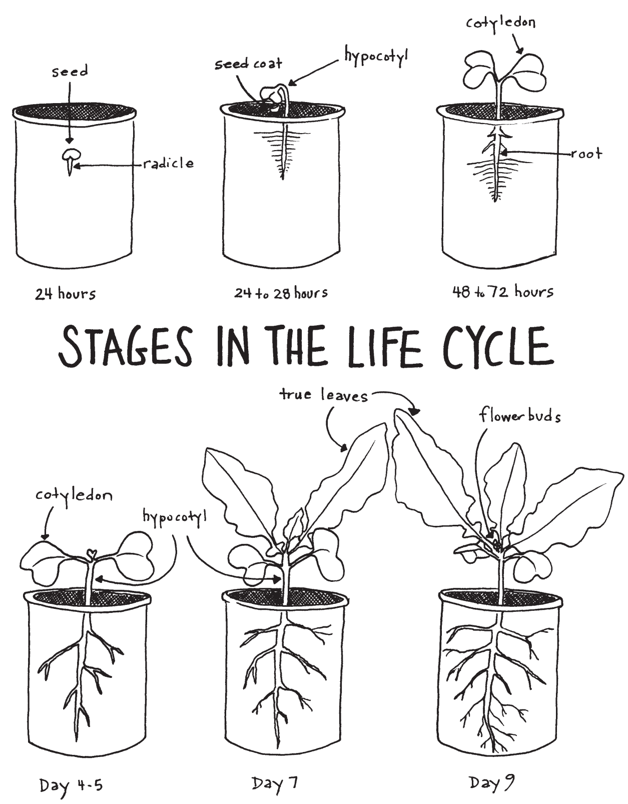
The little *Brassicas* on the Nepalese farm had been grown for hundreds of years in the same location. Because of their isolation, they represented a unique plant stock. That is, these plants had genetic information that was different from other *Brassica* plants anywhere else. The scientist considered them a new plant variety. The explorer knew the importance of saving this different plant type. It is important because different varieties of plants might have the genetic code for variations in traits that can survive environmental stresses. She collected some of the seed of this *Brassica* variety to take home to the US. The seed was stored in the United States Department of Agriculture's *Brassica* seed bank at Iowa State University in Ames. The seed was stored in the collection for many years, though no one seemed particularly interested in it.

However, in the late 1980's a plant scientist at the University of Wisconsin was seeking new genetic material for his research on *Brassicas*. He was trying to discover how to breed vegetable *Brassicas* like cabbage, broccoli, and turnips so that they wouldn't get particular diseases. Plants in the *Brassica* family can get diseases with names like "black leg," "soft rot," and "yellows." These diseases are caused by fungi, bacteria, and viruses. Plants that don't get these diseases are called ***disease resistant***.

The scientist heard about the *Brassica* seed collection in Iowa and wrote to the curator, asking for samples of different kinds of *Brassica* seed varieties. When the seeds arrived, he planted them outside in a field called a research plot. There, in the middle of the research plot, appeared the little, weedy *Brassica* from the mountains of Nepal. That scientist was Paul Williams.

Paul noticed the little *Brassica* right away because it flowered much more quickly than any other *Brassicas*. Some *Brassica* plants are slow to flower, and don't grow very quickly. This means that if a scientist is trying to crossbreed different plants with one another, the research can take a long time. For example, it can take a year to crossbreed cabbages. But this *Brassica* grew very quickly, and from this, Paul got an idea. What if he could use this plant in his research to develop a really fast flowering plant that he could use to test for disease resistance?

He knew he would have to change the plant's environment to discover how quickly he could make the plant grow. Paul saved the seeds of these first plants, then planted those in a



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greenhouse. He grew the new plants under constant light, and with only a small amount of soil. Changing the amount of light and soil introduced an environmental stress. For some of the plants with particular traits, these conditions encouraged plants to grow quickly.

Paul selected from everything he grew the plants that were shortest and sturdiest, that flowered the fastest, and that produced the most seed. He saved seeds from those plants. He was selecting plants with the greatest *reproductive success*. Then he planted those seeds, and grew more plants.

Paul continued to grow generations of *Brassica* plants until he created a "model plant" that he could use to crossbreed with disease-resistant *Brassicas*, and test his results quickly. He called his model plants "Fast Plants." After thirty years of selecting and breeding Fast Plants, Paul developed a new type of plant that germinates in just one to two days. His plants produced flowers in just fourteen days!

In the same way that he had learned about *Brassicas* from the work of other people who came before him (the Nepalese farmer, and the plant collector), this scientist passed on the knowledge of Fast Plants to other scientists. These other scientists discovered different uses for the plants in their research. Today, scientists, students, and teachers are all working with Fast Plants. They are studying how plants grow, and how they produce new generations of plants. Thus the weedy little *Brassica* from Nepal became the great, great…grandmother of the Fast Plants.

Some students will go on to become plant geneticists, molecular biologists, and plant breeders, and they will write the next chapter in the story of Fast Plants.

How do you think it will end?