Dry Forest

Concepts
Scientific data collect ion and presentation

HCPS III Benchmarks
SC6.1.1, SC6.1.2, SC6.2.1

MA6.9.1, MA6.11.1, MA6.12.1, MA6.13.1

LA6.1.1, LA6.4.1, LA6.4.2, LA6.5.2, LA6.6.1, LA6.6.2, LA6.6.3, LA6.6.4, LA6.6.5

Duration
2-3 weeks;
2 class periods to develop and set up, then 15 minutes every other day to maintain their experiment until (another week or two), class period for presentations.

Source Material
Planting Science

Vocabulary
experimental design
variable
biotic
abiotic
substrate
pollution

Lesson 6: Seed Germination

Summary

The students will design and conduct their own experiments based on some general background information presented here. This experiment will be based on seedling germination and plant growth. Students will come up with their own variables to test and then conduct their own experiment. They will create a poster presentation of their research project.

Objectives

- Students will be able to understand the basic requirements for plant growth.
- Student will develop questions to test for a scientific experiment.
- Student will follow scientific method by carrying out the experiment they develop.

Materials

Activity 1: Group Discussion Series
Poster Board for Driving Question Board
KWL worksheet
Scientific Method Chart

Activity 2: Seed Germination Experiment
Seed Germination Procedure worksheet
Lab Report Guidelines worksheet
Seeds (bean plants work well)
Cups & Potting soil or Paper towels & Plastic bags
Water
Ruler
May need depending on experiments:
Colored saran wrap as light filter
Desk lamp
Soda
Gravel
Whatever else the students come up with that is easily obtained
Poster paper (1 sheet per group)
Graph paper
Seedling Growth Word Search

Making Connections

Students will make connections to “Lesson 2: Seed Types” and “Lesson 4: Scientific Method” by using knowledge they have gained in these lessons to create their own experiment on seed germination.

Teacher Prep for Activity

Prep will vary from day to day, but initially a copy of the flow chart needs to be printed large enough for the class to see. The students will also need their notebooks once they start to plan their procedure and question.

The day that the experiment is set up, all of their requested materials should be set out and available to them. They also need to have soil and containers to place their seeds into, depending on their procedure. Make copies of worksheets.

Background

Plant needs:
Plants require certain things to grow successfully. They need **biotic** things like water, light, nutrients, a substrate to grow in, and often a suitable temperature. If these are not optimal for a plant, then its ability to grow can be reduced. They can also be affected by **abiotic** factors such as **pollution**.

When the students begin to design their experiments, they should control everything but one variable. So between the control and the treatment, the only difference would be using Dr. Pepper instead of water (see example below).

Vocabulary:
Experimental design: the methods of an experiment
Variable: the treatment, what is being tested
Biotic: living things
Abiotic: non-living things
Substrate: what plants grow on, dirt, rock, etc.
Pollution: a non-natural effect on the environment, often caused by humans

Procedure

1. Pass out the *KWL* Worksheet and have the students fill out the first two questions.

Activity 1: Group Discussion Series

2. Topic: Scientific Method
   Question 1: What are the steps of the scientific method?

   Answer: The scientific method starts with a general question and is followed by learning background information. Then, a hypothesis can be developed. The hypothesis is then tested by a controlled experiment. During the experiment, results can be collected, which are then analyzed. These results may or may not support your hypothesis. After you analyze your results they can then be reported.

3. Review the scientific method by using the flow chart from the previous lesson (provided below).

4. Topic: Seed Germination

   Create a *Driving Question Board* (*DQB*) by writing "Seed Germination" in the center of a sheet of poster board or chart paper.

   Question 1: What do seeds need to germinate?
   Answer: May include light, soil, water, and temperature.

   Note: Write the students answers on the board or on a separate sheet of paper before adding to the *DQB*.

   Write "Light," "Soil," "Water," and "Temperature," one in each corner, on the *DQB*.

   Question 2: What are different ways that light could affect seed germination?
   Answer: Some answers may include intensity of light, absence of light, color of light, or amount of light.

   Note: Write these answers directly on the *DQB* beneath "Light."

   Question 3: What are different ways that soil could affect seed germination?
   Answer: Answers may include amount, type (sand, clay, etc.), and absence.

   Note: Write these answers directly on the *DQB* beneath "Soil."

   Question 4: What are different ways that water could affect seed germination?
   Answer: Answers could include amount, pollution, quality, and absence.

   Note: Write these answers directly on the *DQB* beneath "Water."

   Question 5: What are different ways that temperature could affect seed germination?
   Answer: Answers may include freezing seeds before or during, keeping seeds warm, and heating seeds.

   Note: Write these answers directly on the *DQB* beneath "Temperature"

Activity 2: Seed Germination Experiment

1. Now, break the students into groups of four to come up with a group name and to develop their own hypothesis to test (for example: Seeds germinated in Dr. Pepper will not do as well as seeds germinated in water.) Pass out the *Seed Germination Procedure* worksheet (1 per student). Make sure the hypothesis is something they can test. Students can measure number of seeds germinated, as well as growth rates of plants after the seeds germinate. This can easily be calculated by dividing height of the plant by the time they have been growing.

2. Now have each group design a procedure to test their hypothesis. Have them write out their hypothesis, materials, procedure (including what they intend to measure), and how

they will compare their data to their control on their worksheet. One copy needs to be turned in from each group to make sure that it is a testable hypothesis and their procedure is something that can be done and that the materials can be obtained.

3. After reviewing the procedure for each experiment (a sample procedure has been included below), have the group look at the adjustments that need to be made. Have the groups edit their procedure on their worksheet.

4. Each group should send someone to get the materials they need to set up their experiment.

5. The groups should follow their own procedure to set up their experiment. Have each student keep their own notes for their experiment because they will be putting together a poster at the end of their experiment.

6. This experiment will be on going, with them watering/monitoring their seeds and plants as often as they decide in their procedure (This could occur everyday, every other day, etc.)

7. After data collection is complete (probably about 2 weeks), students will summarize their data in charts and graphs. These charts and graphs can be made on a computer (excel or power point) or by hand on graphing paper.

8. Have the students write a lab report based on their experiment. Handout the *Lab Report Guidelines* worksheet and review it with the students.

9. The students will then make a poster out of their experiment to put on display for the class. The poster should include their hypothesis, a brief version of their procedure, and their results, including the graphs they made. An example has been included below.

10. Place the posters on display in the classroom. Each group will get up in front of the class and give a short 2-3 minute presentation on their research poster. Afterwards, the students can do a gallery walk, providing constructive and positive comments about each poster by writing it on a sticky note and placing it on the poster.

11. Have the students finish filling out their *KWL* worksheet and turn them in with their *Seed Germination Procedure* worksheet.

Assessments

Student assessment will be done based on the completeness of their *Seed Germination Procedure* worksheet, their poster, and their presentation.

Resources

http://www.sciencebuddies.org/mentoring/project_scientific_method.shtml
http://www.plantingscience.org

Extension Activities

If at anytime, extra work is needed have the students do the *Seedling Growth Wordsearch* worksheet.

Have the students design a new scientific method for seed growth and not germination, or continue on with their experiments to see how their treatment affects the growth of their seedlings.

Sample Procedure

Hypothesis: Seeds germinated and grown in soda will not grow as well as those grown in water.

Materials:
Seeds
Paper Towels
Water
Dr. Pepper
Plastic Bottle
Ruler

Procedure:

1. 10 seeds will be tested as the variable and 10 seeds will be tested as the control.
2. The seeds will be placed on a paper towel on the bottom of a plastic bottle. A different plastic bottle will be used for each treatment (control and variable).
3. Each paper towel will be dampened by the liquids (Dr. Pepper and water).
4. The paper towels will be checked daily (except weekends) and moistened as needed.
5. The length of time it takes for each seed to germinate will be recorded (# of days) and a seed will be considered ungerminated after 1 week of no growth.
6. After the seeds germinate, growth will be determined by measuring the height of the plant with a ruler.
7. This will be done for the next week.
8. After the data is collected, the mean number of days it takes a seed to germinate will be recorded for both the variable and the control. This will be displayed in a bar graph, with the x-axis having two categories (water and Dr. Pepper) and the y-axis being the average number of days.
9. The median will also be determined and displayed in a table for the average days to germinate.
10. The average growth for each seedling will be determined and displayed on a similar bar graph. The median will also be determined for seedling growth.

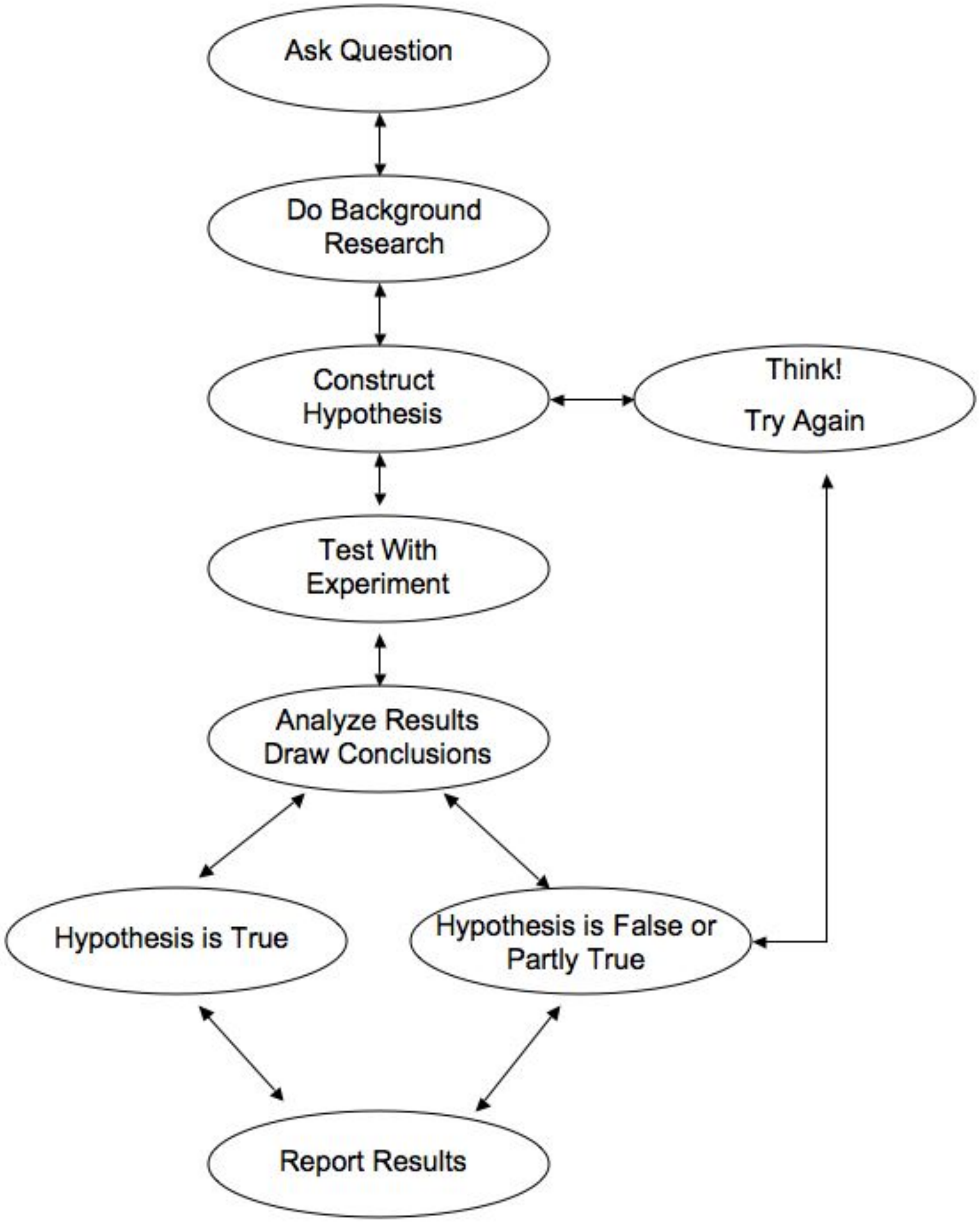
Name: ___________________ **Date: _____________**

Seedling Growth Word Search

d	g	e	f	i	h	e	l	b	a	i	r	a	v
a	x	r	u	o	s	a	n	t	r	q	u	m	l
u	g	w	h	e	j	i	g	a	s	m	n	e	c
s	w	o	i	e	b	m	i	m	e	t	d	b	p
c	o	n	t	r	o	l	s	k	y	r	l	i	o
i	w	o	u	d	l	v	e	w	b	g	k	o	i
e	c	o	n	a	e	d	d	u	u	p	u	t	y
n	n	w	e	k	u	z	l	v	c	a	g	i	u
t	s	p	l	u	q	h	a	e	b	r	a	c	h
i	e	a	c	n	v	h	t	j	c	k	y	l	g
f	w	p	o	l	a	n	n	w	i	s	h	g	n
i	b	e	d	k	l	e	e	k	t	w	r	t	o
c	x	e	j	e	s	t	m	d	o	s	u	f	i
m	e	d	i	a	n	r	i	v	i	b	f	e	t
e	r	i	h	g	e	o	r	s	b	k	n	p	u
t	v	e	r	s	t	i	e	o	a	r	b	r	l
h	e	w	p	s	o	h	p	t	n	a	e	b	l
o	b	w	a	g	t	h	x	y	t	r	e	s	o
d	w	i	t	o	h	g	e	j	c	e	g	b	p
m	n	e	p	r	u	p	w	f	x	e	r	e	f
a	e	y	v	b	s	u	b	s	t	r	a	t	e
w	h	h	j	l	i	d	s	t	y	r	e	h	r

Vocabulary words:
-scientific method
-hypothesis
-experimental design
-control
-variable
-mean
-median
-biotic
-abiotic
-substrate
-pollution

1. something that is being manipulated, circle the answer
2. a prediction, put a line through
3. average, place an X though
4. natural substance, circle and then place an X through
5. a way to answer a question, place two lines though
6. plants grow on this, circle twice
7. the middle point, circle and place a line through
8. important part of scientific method, place a squiggly circle around
9. non-natural and usually man made, squiggly circle with a line through
10. this is what the variable is compared to, place a box around
11. litter, smoke, and other waste, place in a box and put an X through the box


Ask Question
Do Background Research
Construct Hypothesis
Think!
Try Again
Test With Experiment
Analyze Results Draw Conclusions
Hypothesis is True
Hypothesis is False or Partly True
Report Results

Group Name: ___________________ **Date: ______________**

Seed Germination Procedure

Hypothesis:

Why did you choose this as your hypothesis?

Control:

Variable:

Procedure:

Materials:

Steps:

Data and Results:

Conclusions:

Name: ______________ **Date: __________**

Seed germination K-W-L

What do you know about seed germination?

What do you want to know about seed germination?

What did you learn about seed germination?

Lab report guidelines:

Introduction: Should contain background information justifying why you are testing your specific hypothesis. The introduction should end with a clear statement of your hypothesis and expectations.

Methods: Should be a detailed description of how your experiment was conducted. It should be detailed enough that someone else could read it and recreate your experiment.

Results and Data Analysis: This section should clearly describe what your results were and what you did to them to make sense of the data. This includes talking about how and why you made each graph or table.

Conclusions: This section should interpret your results and make some conclusions about your research. If no clear conclusions can be made, it should be used to talk about how you could improve the experiment. This section should also discussion future experiments that could be done based on the knowledge you have obtained through your experiment.

Evolution of reproductive isolation in the Hawaiian tree, *Metrosideros polymorpha,* along an elevational gradient

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Background Information

Reproductive isolation (RI) is important in evolutionary biology because it is a measurable, well-documented indicator of speciation. RI may arise sympatrically, parapatrically, or allopatrically and may be examined by testing cross-fertility between individuals or populations (Coyne & Orr 2004). RI may arise as a byproduct of phenotypic divergence due to ecological pressures (Rice & Hostert 1993) and may involve intrinsic incompatibilities (Gavrilets et al. 2000). Alternatively, RI can be effected by random genetic drift in isolated populations. RI barriers can form either pre-zygotically or post-zygotically (Coyne & Orr 2004).

Metrosideros polymorpha, a common and highly variable native tree species in Hawai`i, dominates a broad range of habitats found throughout the Hawaiian Islands. Some of the more common phenotypic differences among varieties include leaf characteristics such as the presence or absence of pubescence, leaf size, and leaf color, as well as floral color. Flowers of *M.* polymorpha vary from red to yellow, pink, and salmon. Flowers are traditionally pollinated by native birds and insects, but are visited by a wide range of insects (Dawson & Stemmermann 1990). This species is found from sea-level to 2500 m, at temperatures of 10 to 24° C, and in areas with rainfall of less than 400 mm/year to areas with 9900 mm/year (Cordell et al. 1998). The main varieties of *M. polymorpha* appear to reflect divergence along elevational and successional gradients (Burton & Mueller-Dombois 1984). Because of its striking morphological and ecological variation, this species serves as a model system for addressing evolutionary questions.

While morphological divergence along an elevational gradient is well documented in *M. polymorpha* (e.g. Burton & Mueller-Dombois 1984, Cordell et al. 1998), and cross-fertility has been examined between some varieties (Porter 1973, Corn 1979, E. Stacy, unpublished data), reproductive divergence along an elevational gradient remains unexplored. This study examines cross-fertility of *M. polymorpha* along an elevational gradient on east Hawai`i Island.

Different varieties of *M. polymorpha* at the *Metrosideros polymorpha* Common Garden in Volcano, Hawai`i. These trees are being used for cross-fertility studies and morphometric measurements. The common-garden environment reduces the influence of phenotypic plasticity in both studies.

http://www2.hawaii.edu/~eherring/hawnprop/met-poly.htm

Inflorescences of *M. polymorpha.* The typically red, shaving brush like flowers use nectar to attract pollinators like the native honeycreepers. Invasive insects like the European honey bee are also pollinators of these flowers.

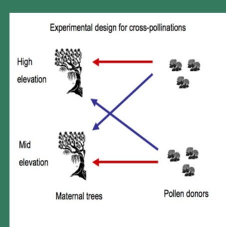
Methods

At both Volcano Common Garden (VCG) and in natural populations, pubescent trees from two elevational categories are being selected for cross-pollination. Four inflorescences, with approximately 10 flowers each, are being targeted on each maternal tree. Before the buds break, they are covered with a mesh bag. As the stamens emerge, they are removed to prevent self-pollination. Four to eight days after the style emerges from the flower, depending on the elevation, the flowers are hand pollinated. For all hand-crosses, pollen from three to four unrelated donors is pooled in order to create a better representation of the population.

At VCG, pubescent trees from populations at 1280 m, 1980 m, and 2470 m are being used. A common-garden setting was chosen in order to eliminate the effects of phenotypic plasticity, but the number of flowering trees in the garden is limited. Hand pollinations will be done in natural populations at elevations of 920 m, 1980 m, and 2470 m. In both cases, the two higher populations will be combined into the "high-elevation" category. At VCG, eight maternal trees from each elevation, both mid and high, are being targeted. In natural populations, 20 trees from each elevation are being targeted.

Fruits resulting from hand-pollinations are allowed to mature until they are ready to dehisce and then are collected and left to open in the lab. Rates of fruit set, seed set, and seedling germination will be determined for each cross.

Paired t-tests will be done for each maternal tree to examine differences between inter- and intra-elevational crosses for fruit set, seed set, seed germination, and cumulative cross-fertility. A difference score will also be determined based on these data and used in a two-factor ANOVA comparing maternal and paternal effects on cross-fertility.



Experimental design for hand pollinations across an elevational gradient. Maternal trees receive pooled pollen from trees from the same elevation as well as pooled pollen from trees from a different elevation for comparison. Approximately 20 flowers will be pollinated for each cross (~40/ maternal tree).

Research supported by NSF Research Initiation Grant 0542350

High-elevation field site (2470 m) on the slopes of Mauna Loa on East Hawai`i Island.

Two varieties of *M. polymorpha.* On the left, *M. polymorpha* var. *incana (mid-elevation)*, on the right, *M. polymorpha*, var. *polymorpha (high-elevation).*

Results and Discussion

Cross-pollinations of populations are underway along an elevational gradient and in a common garden. Preliminary results (differential fruit abortion) suggest some reduced cross-fertility between populations at different elevations. For crosses done in the high-elevation natural populations (five fully completed), 1.8 more fruits are aborted when pollen comes from a different elevation.

The elevational varieties of *M. polymorpha* are distinct at the extremes, but overlap at a intermediate elevations (Cordell et al. 1998). Both genetic drift and natural selection may cause morphological differences to develop between mid- and high-elevations. Genetic drift could be eliminated not only through long-distance pollen flow, but also through long-distance dispersal of seeds. Seeds of this species are small and carried by the wind (Drake 1992). It is unknown how far the seeds travel or if seeds can germinate and establish in environments of different elevations. If this study reveals no reduction in cross-fertility between populations, this might indicate that genetic drift is not playing a large role in the morphological differences between the populations. As cross-fertility between populations becomes reduced, the potential role of genetic drift should increase (Coyne & Orr 2004).

Metrosideros polymorpha is a relatively young species. The progenitor of Hawaiian *Metrosideros* arrived in the Hawaiian Islands via the Marquesas Islands as early as 4 mya (Percy et al., in review) or as late as 0.5 - 1.0 mya (Wright et al. 2001) by wind dispersal (Drake 1992). Since that time, the group has diversified into five named species, including *M. polymorpha*. Observations of apparent hybrids among varieties of *M. polymorpha* (Corn 1979, Burton & Mueller-Dombois 1984) indicate that reproductive divergence along environmental gradients is incomplete. Observation of partial RI between populations in the current study would indicate that divergence along an elevational gradient is a means of incipient speciation in trees.

Placing mesh bags over buds before they open to prevent pollination by floral visitors. As the experimental flowers emerge, they are emasculated in order to prevent self-pollination.

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