

Engineering High School Biology into the 21st Century



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LRDC
Learning Research &
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Beginning a New Era of Science Instruction?

Until now

- rapid topic march
- skills vs. concepts
- another teaching silo
- (procedural) mathematics on the way out
- engineering ignored

Moving forward

- focus on big ideas
- integrated skills & concepts
- embracing **STEM**
- conceptual mathematics and simulation demanded
- engineering integrated



Engineering in NGSS

1. Asking questions (for science) and **defining problems (for engineering)**
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations (for science) and **designing solutions (for engineering)**
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

Math

Science

M1. Make sense of problems & persevere in solving them
M6. Attend to precision
M7. Look for & make use of structure
M8. Look for & express regularity in repeated reasoning

S2. Develop and use models
M4. Model with mathematics

S5. Use mathematics & computational thinking

S1. Ask questions & define problems
S3. Plan & carry out investigations
S4. Analyze & interpret data

E2. Build a strong base of knowledge through content rich texts

E5. Read, write, and speak grounded in evidence
M2. Reason abstractly & quantitatively
M3 and E4. Construct viable arguments & critique reasoning of others
S7. Engage in argument from evidence

S6. Construct explanations & design solutions
S8. Obtain, evaluate & communicate information
E3. Obtain, synthesize, and report findings clearly and effectively in response to task and purpose

M5. Use appropriate tools strategically
E6. Use technology & digital media strategically & capably

E1. Demonstrate independence in reading complex texts, and writing and speaking about them

E7. Come to understand other perspectives & cultures through reading, listening, and collaborations

ELA

Is the mathematics
about procedures or
understanding?

HS-LS3-d.

Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population.

HS-LS4-c.

Apply concepts of statistics and probability to support explanations for how organisms with an advantageous heritable trait tend to increase in proportion to organisms that lack this trait.

The Landmine Crisis

A 3-week-long

Engineering Design Challenge

(Replacement unit)



<https://www.youtube.com/watch?v=5NkwLJgoYFO>

Laos



UXO: A major problem

- Unexploded Ordinance
- From 1964-1973, US forces dropped roughly two million tons of ordinance on Laos (more than in all of WWII).
- With 37% of the country's total surface area contaminated by UXO, Laos is considered the most UXO-affected nation in the world.

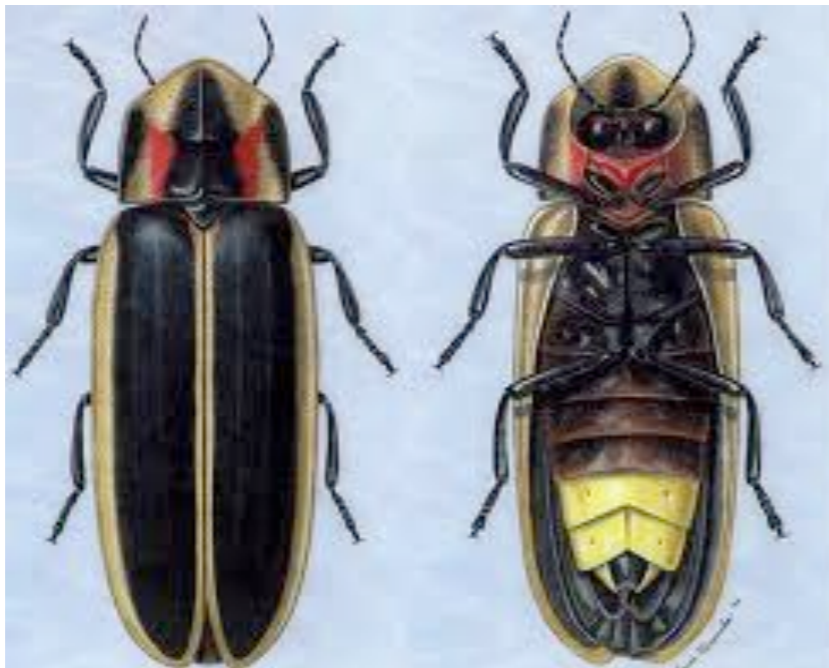
What can be done?



- We are a team of volunteers who have offered our services to Engineers Without Borders
- The mission of EWB is to "support community-driven development programs worldwide by collaborating with local partners to design and implement sustainable engineering projects"
- EWB has assigned us to tackle the landmine challenge in Laos

No Free Lunch

- Our project is financially supported by Phil, who has an idea:



Student Activities

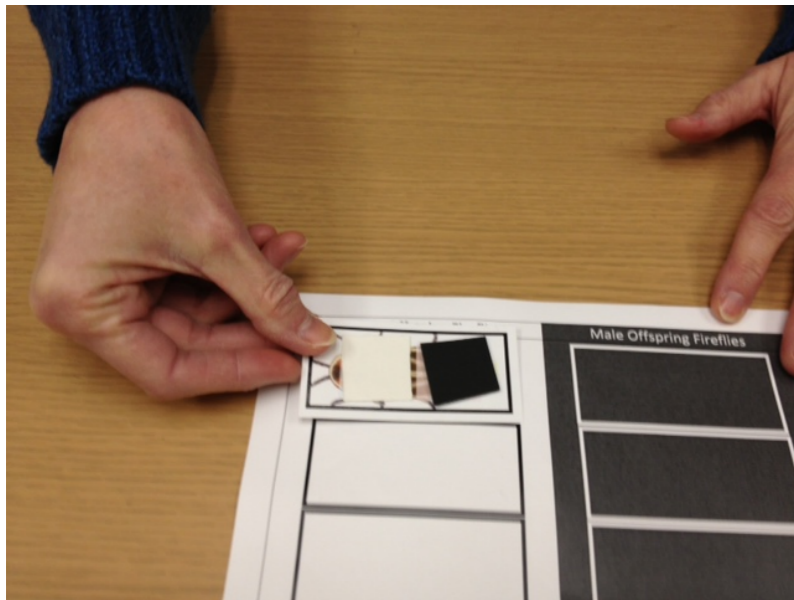
- Identify resources and constraints
- Generate problem statement
- Conduct background research on fireflies
- Develop a plan to purchase and breed flies in order to get more special fireflies

BUT: We don't really know much (anything?) about firefly reproduction!

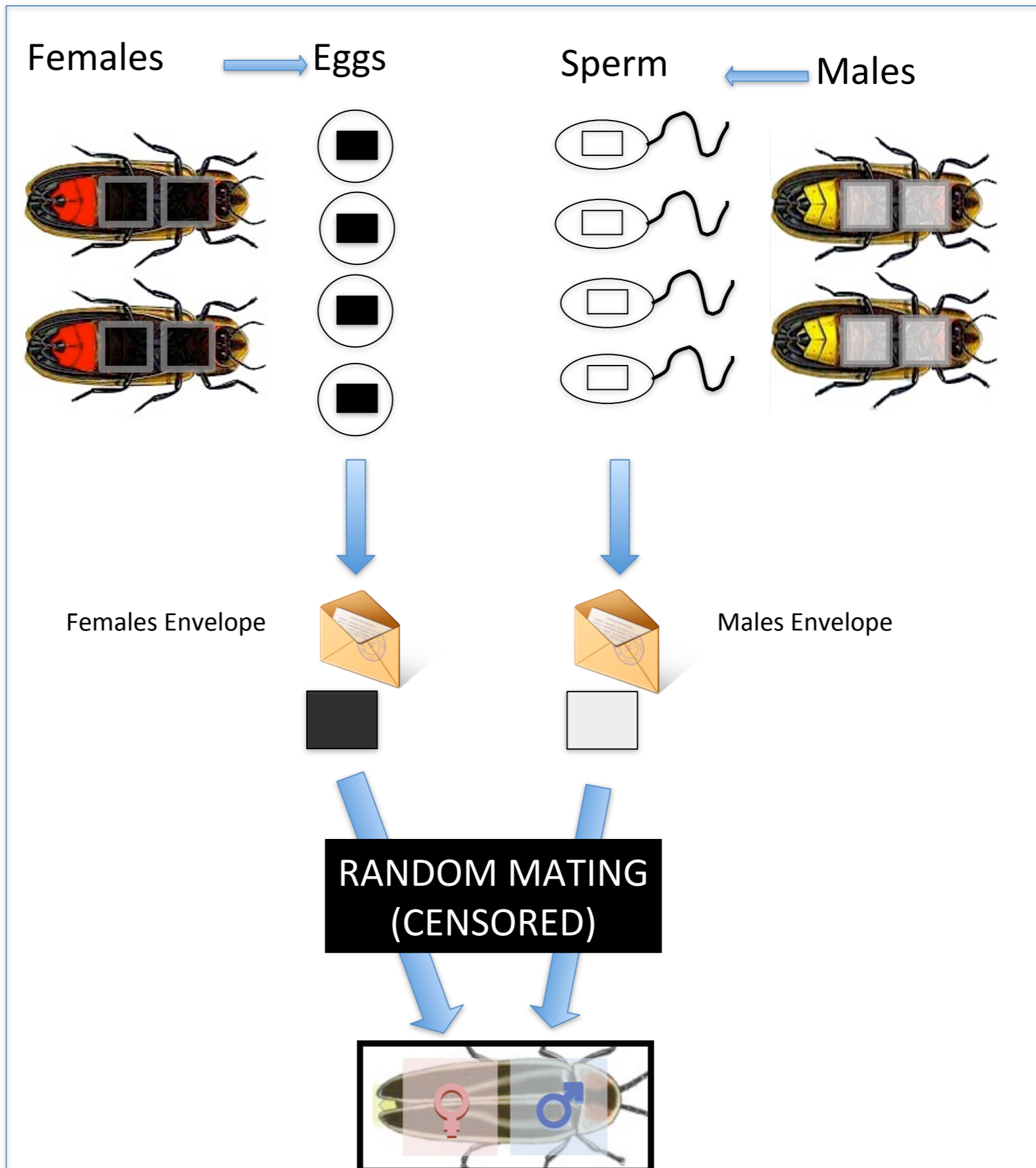
What would happen in a sealed environment?

Testing the simple case

- Use a simulation!



Generation 0: Initial Population



Parents

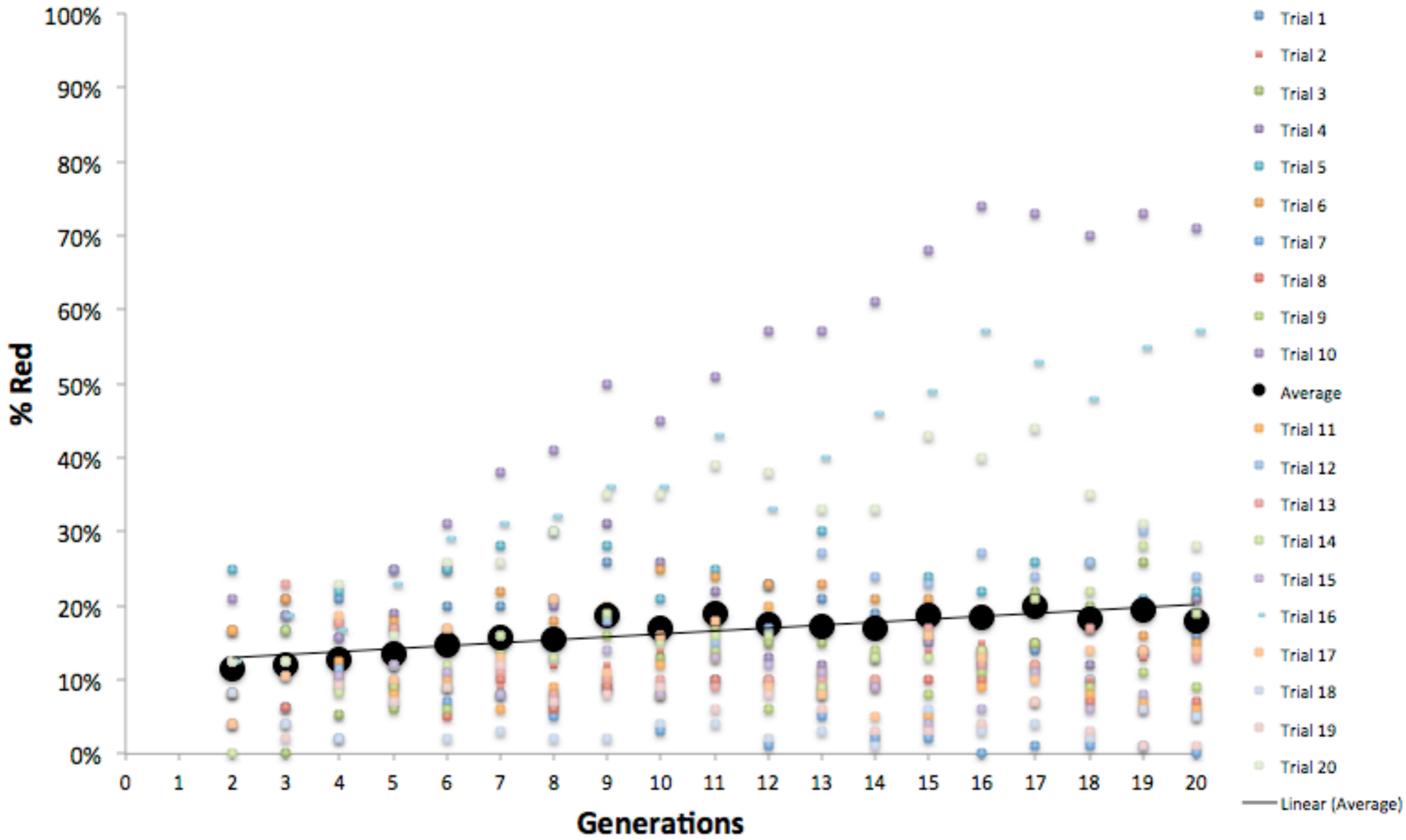
Alleles packaged into gametes (eggs & sperm)

Gametes join during fertilization

Offspring (Gen 1) get one allele from each parent

Excel + Computational Thinking

% Red Fireflies Over Time



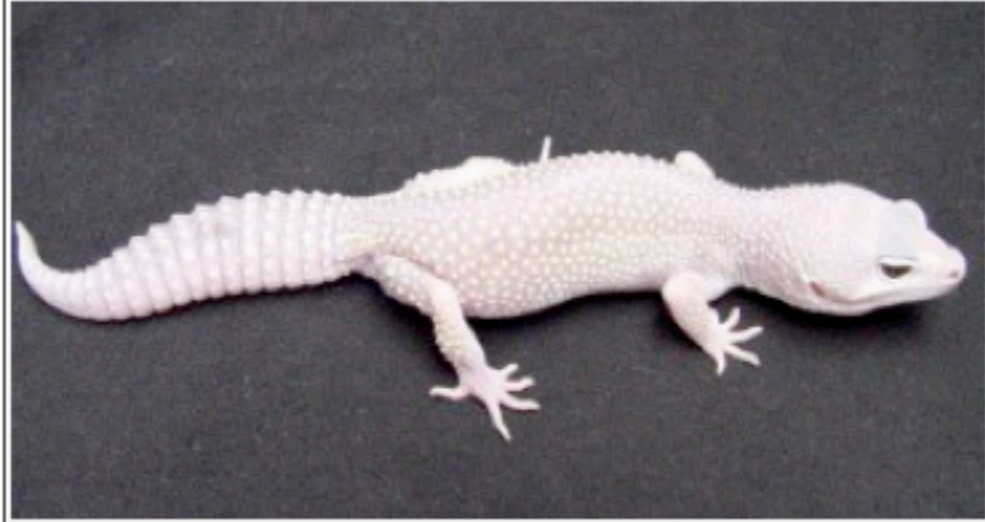


Biology Content

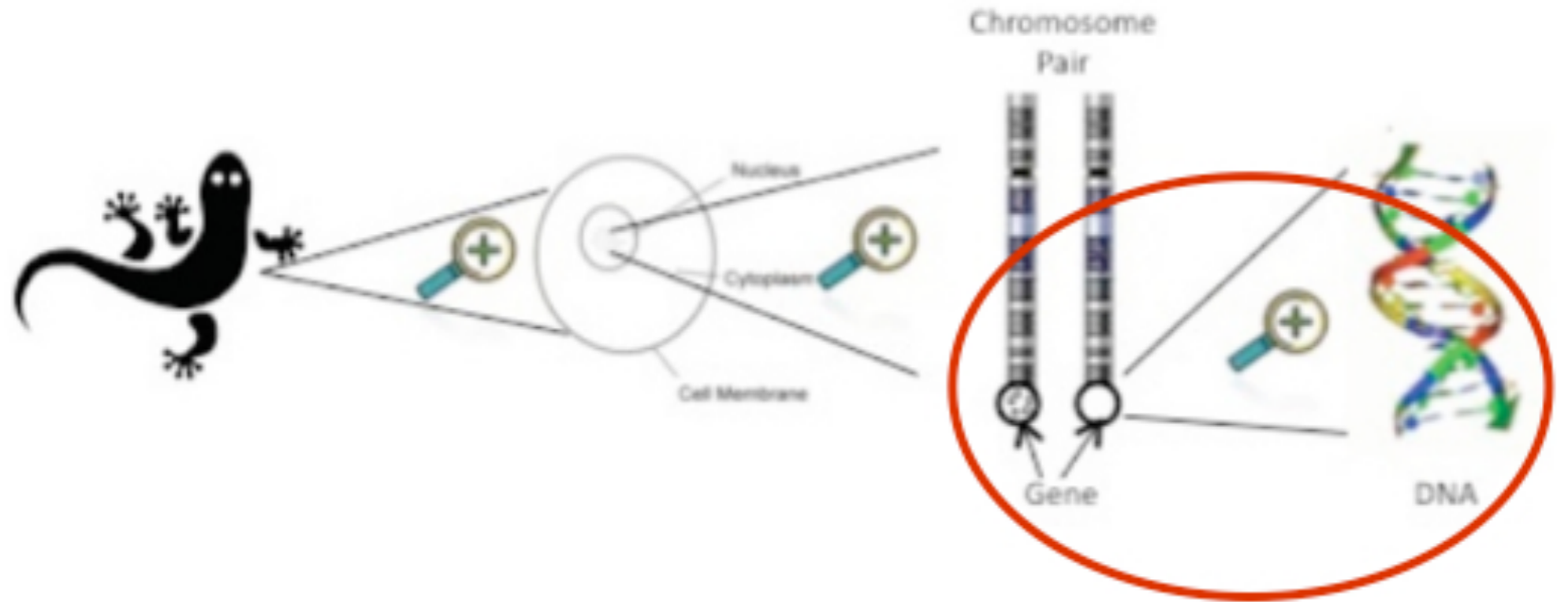
- Goals:
 - Environmental factors (selective pressure) acts on the phenotype.
 - When selective pressure differentially affects survival of one phenotype in a population versus the other phenotype, the proportions of alleles and phenotypes within the population changes.
 - As selective pressure acts on a particular phenotype. then,
 - the phenotype with a higher pressure will decrease at a certain rate, but
 - the phenotype with lower pressure will increase at the same rate.
- This is Evolution by Natural Selection!

Math Content

- Goals:
 - The change in percent phenotype/alleles which is expressed on the y axis divided by the change in time (expressed on the x axis) is a measure of the rate of change (slope) in the population.
 - Across multiple trials, the best model fit can be captured with the slope of the best fit line, which is the average of the slopes of all the trials
 - A positive slope indicates that the variable on the y axis is increasing over time. A negative slope indicates that the variable on the y axis is decreasing over time. (x-axis represents time)
 - The steeper the line, the larger the numerical value of the slope and the faster the rate of change.

Type of Leopard Gecko	Picture	Gene	Cost
Normal		N/A	\$35 or \$70
Albino		Albino	\$80
Blizzard		Blizzard	\$80

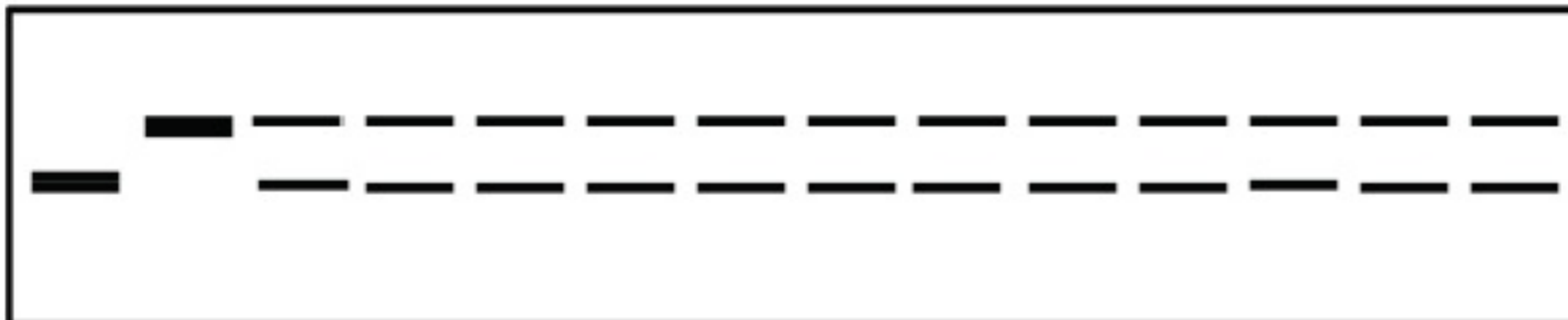
PCR data

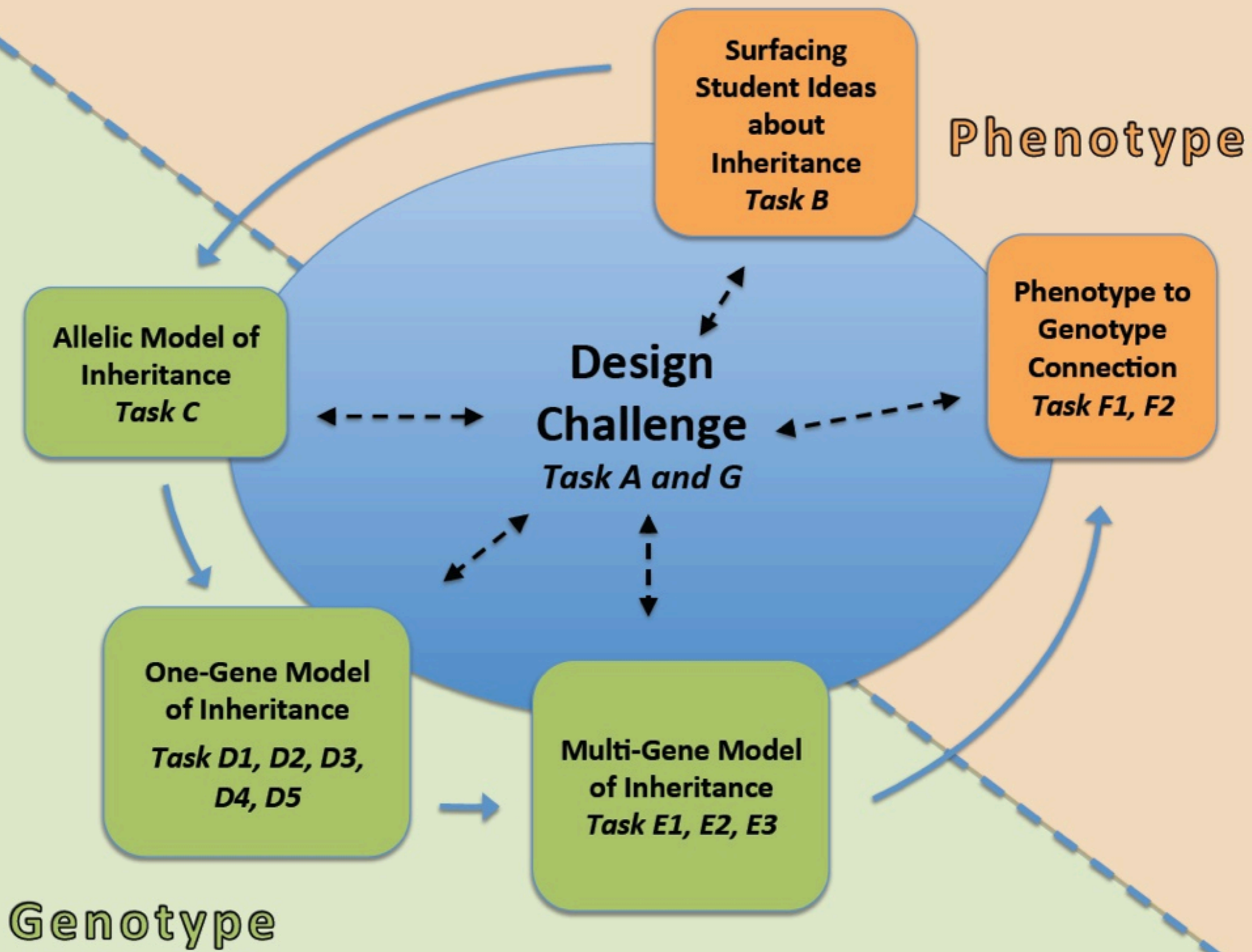


F1 M1 O1 O2

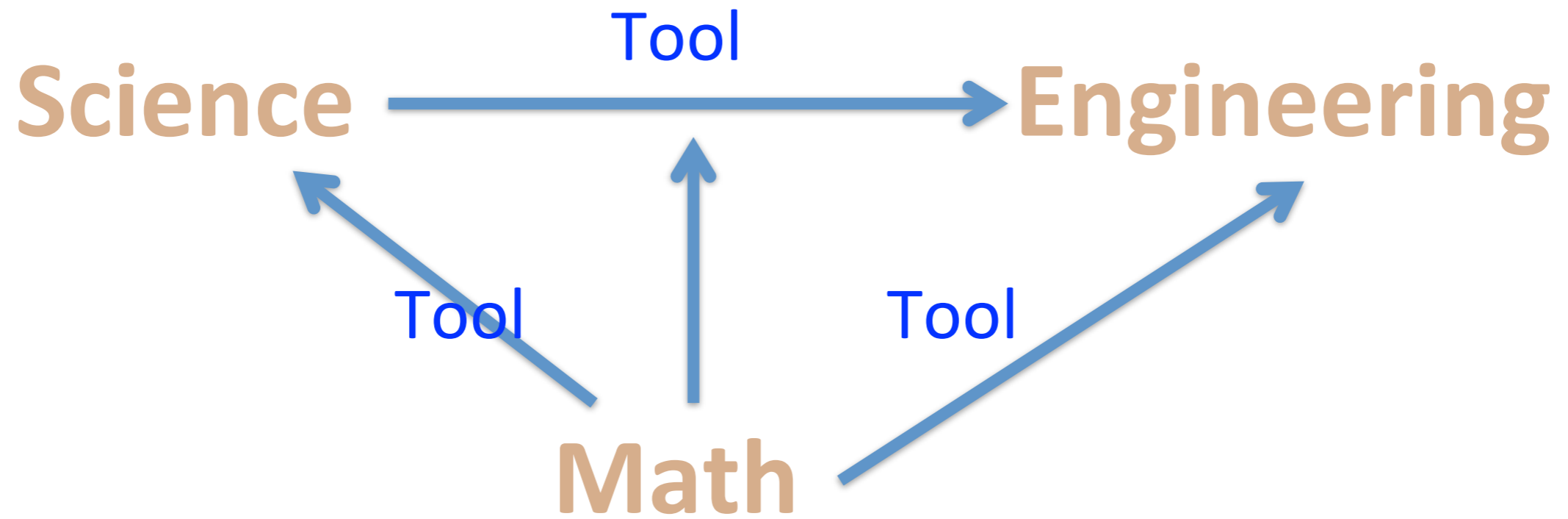


F2 M1 O1 O2 O3 O4 O5 O6 O7 O8 O9 O10 O11 O12

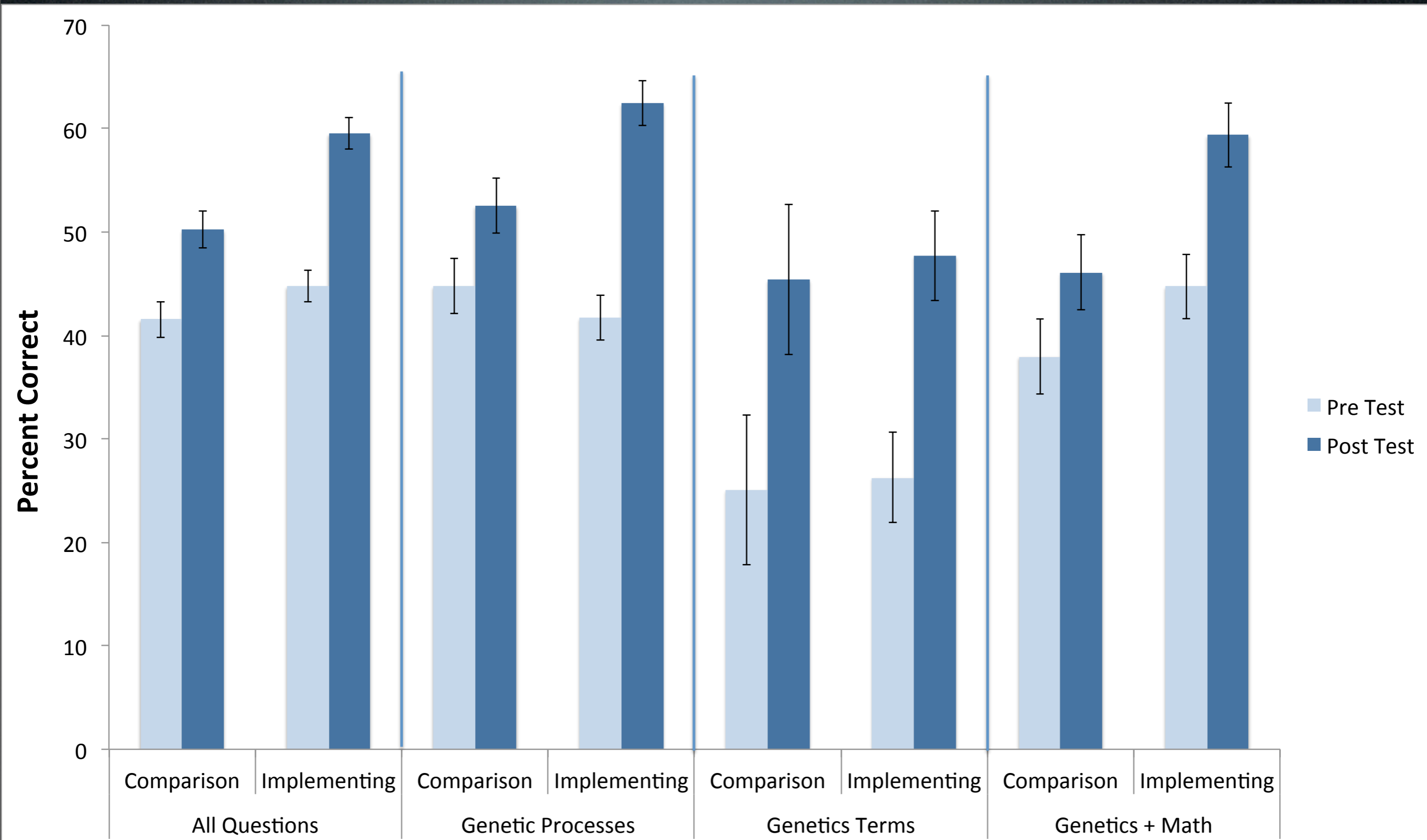




STEM?



What about test data?



I liked the discovery and process of learning about the genes and how they're dominant/recessive and which allele is passed down. I found it interesting!

Fun, hard, interesting.

This had me physically involved and kept my mind thinking.

Challenged, engaged, interested

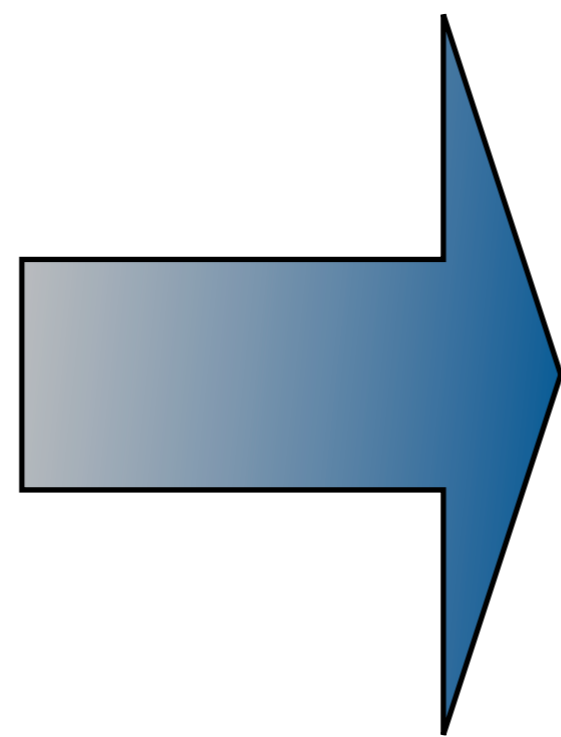
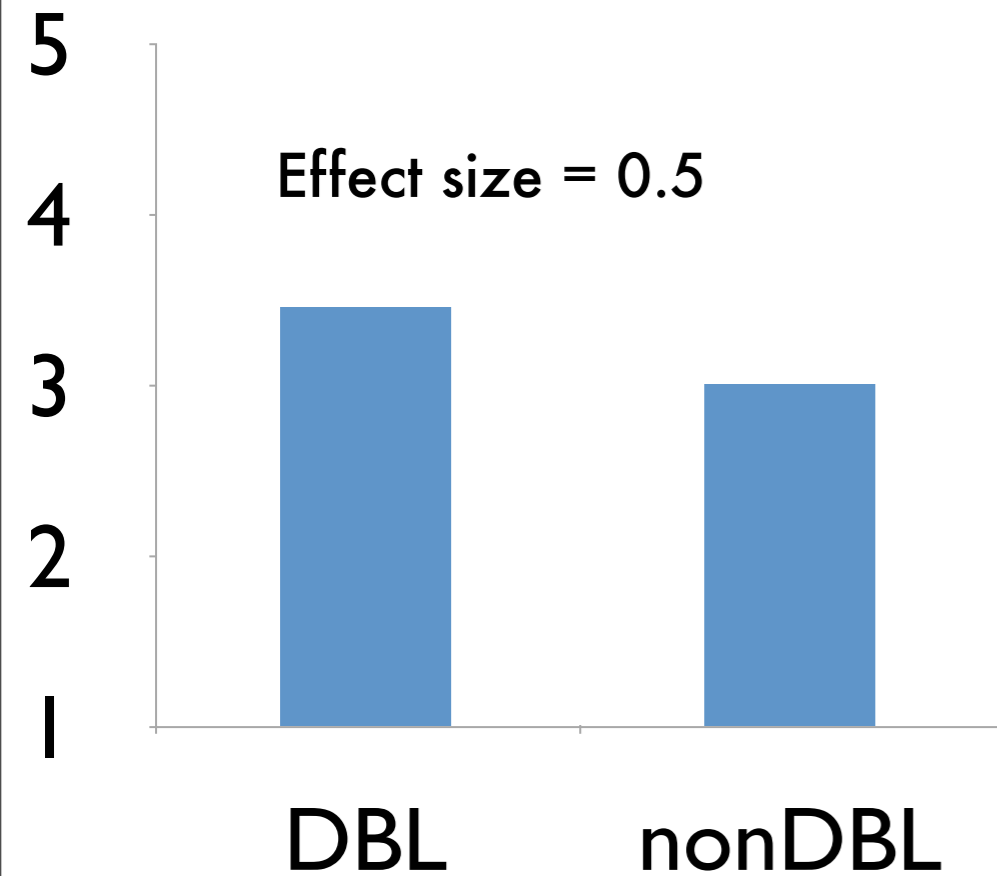
Fun, inspiring, fascinating

I found learning about gecko genes very enjoyable. I enjoy this because it unlocked my loves for genes

It made you feel excited that you finally understood what the point of making rare geckos is. You get excited when you realize that you know how to do this.

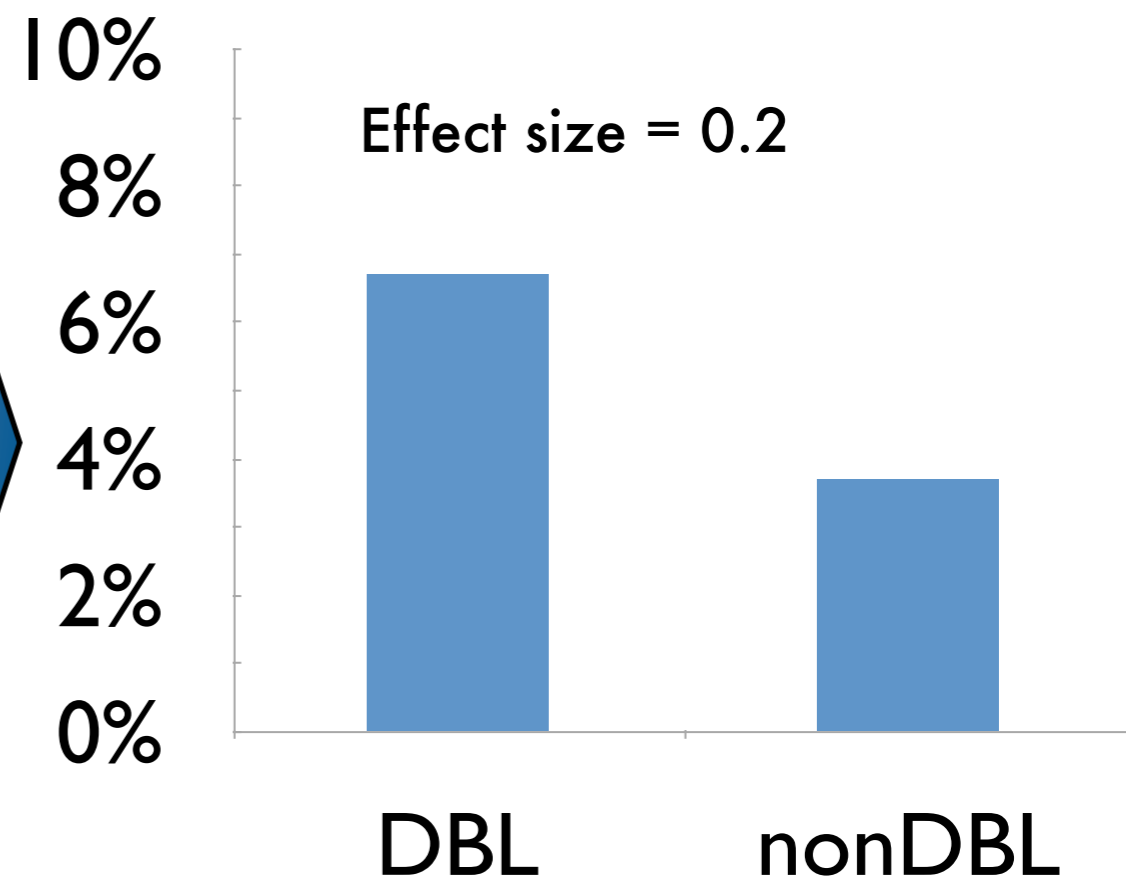
Engineers understand how to solve people's problems

(mean Likert Rating)



Very likely to become engineer?

(% of students)



Relative effect size:

- .3 of gender Effect
- .4 of Parent engineer effect
- .5 of Minority effect



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Unit Overview

Task A: The Landmine Crisis

2 class periods

Working like engineers to understand a societal problem about landmines will motivate students to learn about growing a population of fireflies.

Task Segments

- A.1: The Landmine Design Challenge
- A.2: Exploring a Potential Solution
- A.3: Clarifying the Problem
- A.4: Conducting Background Research
- A.5: Planning For Design

Task B: Modeling Population Growth

3 class periods

Through collaborative discourse with the teacher, students explore concepts about population growth using a reproduction simulation.

Task Segments

- B.1: Introducing Concepts about Population Growth
- B.2: Exploring Population Growth with Simulation

Task C: Analyzing Simulation Results on Population Growth

3 class periods

Students explore data generated from the simulation by using mathematical tools to understand that growing a population increases the number of all types of flies in the population proportionally.

Task Segments

- C.1: Generating Graphs
- C.2: Fostering Proportional Reasoning
- C.3: Discussion on storyboards and graphs
- C.4: Discussion about Constructing Design Criteria

Task D: Extending the Simulation

3 class periods

Students use a computer simulation to explore in what ways selective pressure influences the proportion of a particular trait in a population of fireflies.

Task Segments

- D.1: Introducing the Devices
- D.2: Using the Excel Simulation
- D.3: Interpreting Simulation Data

Task E: Proposing a Solution to the Challenge

2 class periods

Students use a computer simulation to explore in what ways initial population influences the proportion of a particular trait in a population of fireflies.

Task Segments

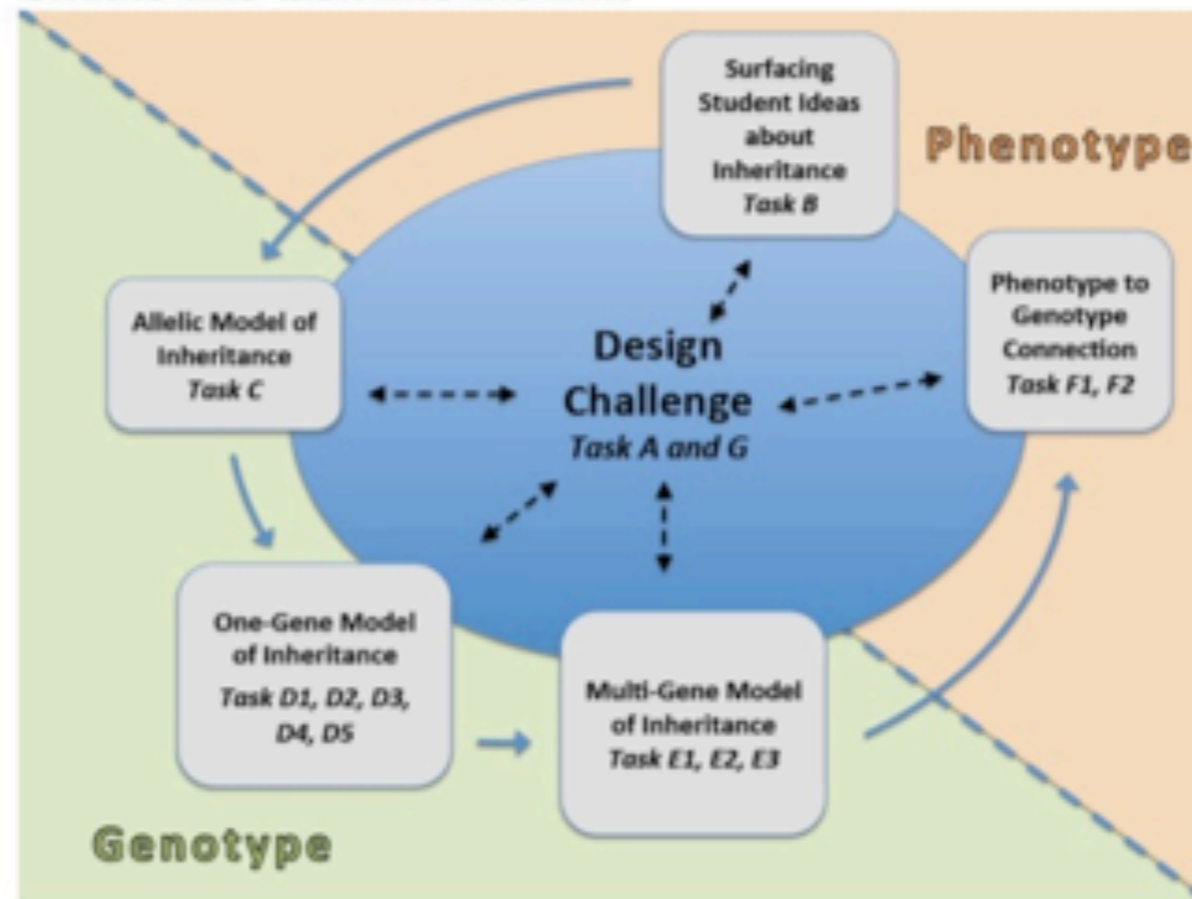
- E.1: Reviewing and Brainstorming Options
- E.2: Reporting Back to Phil

Task A: Design Challenge: First Exposure

Task Description:

Exploration of the zoo's design challenge sparks interest in learning about inheritance and probability.

Situate this task into the unit



Tools & Worksheets for Each Task Segment:

A.1: Making Sense of Breeding Challenge Information

- [Worksheet 1A \(pages 1-4\)](#)

A.2: Brainstorming Initial Solutions

- [Worksheet 1A \(page 5\)](#)

Why this task now?

By tapping into students' ideas about zoos and breeding as well as their entrepreneurial interests, the design challenge helps students see genetics knowledge as useful in a real world context. This initial task is meant to help students begin brainstorming a solution so they can take ownership over their work in this unit.

Content Goals

Biology Content Goals

Although this task has no specific biology content goals, it lays the foundation for future content by motivating students to learn how traits are inherited.

Mathematics Content Goals

This task sets the stage for the unit's mathematics work. In particular, it encourages students to begin thinking about rarity as an infrequent occurrence.

Scientific/Engineering Practices

NRC Practice-1: Defining Problems (Engineering Practice)

"(Engineers begin) with a problem, need, or desire that suggests an engineering problem that needs to be solved....(They) ask questions to define the engineering problem, determine criteria for a successful solution, and identify constraints." (NRC, 2012)

Students will define the problem about the gecko breeding challenge by:

- identifying the engineering problem posed by the zoo's challenge,
- identifying resources available for solving the challenge,
- defining constraints imposed within the description of the challenge presented by the local zoo, and
- generating questions that reflect knowledge or information needed in order to solve the design challenge.

Moving on from here

By engaging in engineering practices of defining the problem, students will recognize a need to understand how inheritance works and how to define rarity in order to solve the zoo's challenge. Some questions from this task to motivate the work in the rest of the unit:

- What offspring do we get when we breed what we can afford? (addressed in exploration of inheritance patterns)
- How do we determine what counts as rare? (addressed in development of mathematical expressions)

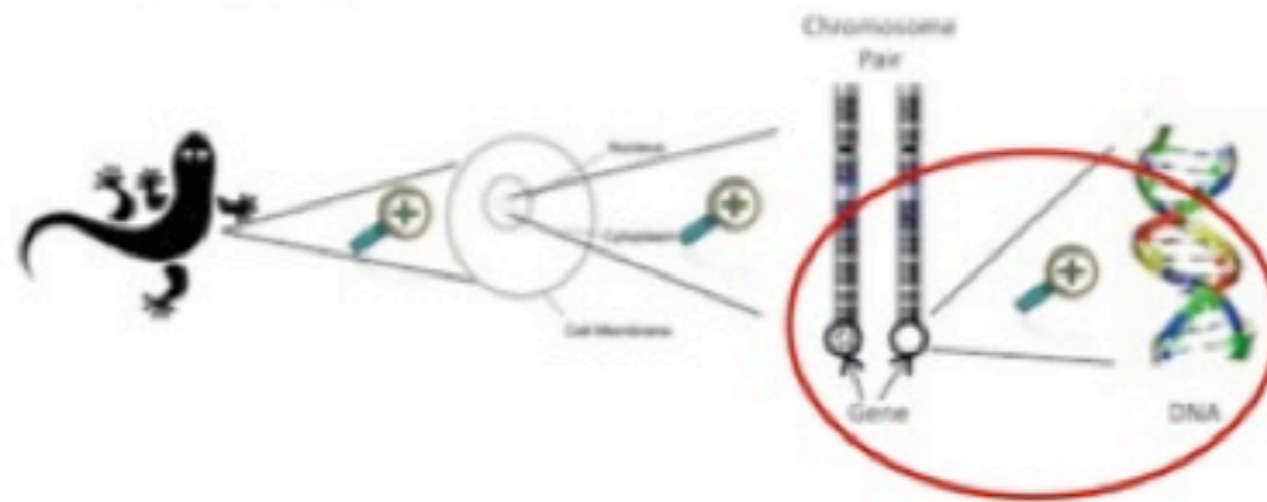
Segment C.1.1 On Data

Resources: Worksheet 3A (pages 1 & 2)

Setting Up Task by Connecting Back: Whole Class [5 min]

Purpose: To help students understand that, to learn about hidden factors, they need to explore inheritance at the gene/DNA level.

- Revisit the need to learn about hidden factors inside geckos (from Task B).
- Teacher presents the Gecko Zoom video and leads a brief review of levels of organization.
- Teacher hands out pages 1 and 2 of Worksheet 3A.
- Students circle the level they think the worksheet is addressing. [NOTE: Students should recognize that, in this task, they will be working at the gene/DNA level.]



Monitoring Student Thinking and Seeding Ideas: Small Groups [10 min]

Purpose: To help students observe patterns in the PCR data that will support development of rules of inheritance in Segment C.2.

- Teacher sets up activity by asking, "What is an observation?"
- Student groups record observations about the PCR data to share with

Important

With seeding, you can avoid having to provide the same support to all groups during group work. Instead, you can “plant” an idea (concept or process) within one or two mid-level groups. During the class discussion, you can use the “seeded” groups to get the same idea across to the rest of the class.



Observations	Inferences
All the offspring in cross 2 have the same PCR.	All the offspring in cross 2 look like a blend of the two parents.
In cross 1, some offspring PCRs match the mom's and some match the dad's. In cross 2, none of the offspring PCRs match either parent.	In cross 2, offspring 1, 5, 7, 8, and 10 are boys because their PCRs look like the dad. The others are girls. In cross 2, all the offspring are girls.

Guiding Students to Consensus: Whole Class [10 min]

Purpose: To enable students to agree on a list of PCR observations that they will use to develop rules of inheritance in segment C.2.

- Teacher asks students for observations.
- Class decides whether each contribution is an observation or inference.
- Teacher records the observations on chart paper for use in generating the rules of inheritance.

How other teachers customized this Segment for their classroom



**Laura
Ploughe**

Classes: Environmental Science (Grade 9th),

Wednesday, February 13, 2013 at 7:43 am

In order to incorporate geography into the unit, I utilized Google Earth and maps to show students where Laos is.

Also, my students were having some difficulties understanding why exactly they were looking at the key features, so I also had the students identify their problem statements on their whiteboards in addition to the 4 features. When they did this, they were able to generate their key features easier as they understood the purpose for the task.



**Denise
Davis**

Seton LaSalle Catholic High School

Classes: General Biology (Grade 10th), Honors Biology (Grade 9th),

Thursday, February 7, 2013 at 5:50 am

I showed the film first and then brought up a google map of Laos with the satellite view. The topography of the land help the students to see the lay out of the land. I feel this enabled them to see the difficulty in locating the landmines and brought a better sense of isolation.

DISCUSSION: Device 3 with full vials

1 Comment

After working with Device 1, 2 and 3, I had a group that requested to have more flies to breed with device 3 since their extinction percent was present. I allowed them and they got above 75% red flies surviving by generation 4 with 0% extinction. Do I push them to ask for heterozygous flies if they think they have solved the issue or let them write their conclusion. They won't realize they could have slightly better results with het flies until other groups present their conclusion. So they aren't wrong just not as efficient.

kdp5@pitt.edu

Curriculum Developer

Wednesday, February 27, 2013 at 11:11 am

Curriculum Developer

Hi Angie,

[C.1: Generating Graphs](#)

[C.2: Fostering Proportional Reasoning](#)

[C.3: Discussion on storyboards and graphs](#)

[C.4: Discussion about Constructing Design Criteria](#)

DISCUSSION: Is Orange Color Ok?

1 Comment

My one class wanted to vote on 60% red flies being a strong enough color change in the vial from the yellow. Is orange ok?

Mary Sartoris

Curriculum Developer

Monday, February 11, 2013 at 8:01 am

Curriculum Developer

Next Steps

- Optional Summer workshop (2 full days/unit)
 - August 12th-16th
 - Oakland County, MI (Just north of Detroit)
- School Year
 - 2 virtual workshops (before + during)
 - Materials can be purchased at cost (whiteboards + simple hands-on)
 - free iPlan access

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