Lesson Plan For "Catch a Mimic: Natural Selection"

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www.Embodied-Games.com

Length of Game: 8 Minutes. (If all six levels are played.)

Grade Levels: Grades 4th through 10th. (Or, up to lifelong learners.)

NGSS Standards – See Appendix at end.

Rationale/Aim:
Students will actively engage in learning how certain species evolve over many generations and appear to "mimic", or copy, others. The game stresses that **it takes many generations**, a long time, for mimicry to occur, and that this happens through natural selection. It is important for students to understand that an organism **does not intend to change**, alter a biological trait, such as its physical appearance.

Structure of Game:
There are six levels total, they are in two sets of 3. The first 3 levels contain orange and yellow butterflies; the second set (levels 4, 5 and 6) contains blue and white butterflies with spots. The second set is more difficult to play. At the end of level 2 and level 5, there are interactive bar charts for the students to digitally fill in.

Minimally, students should play to the end of level 3. The second, harder set reaffirms what they learned in the first set, or gives them a chance to learn the concepts, if they did not on the first set.

Data of Score Saving:
There is no "data saving" after a player exits. You may ask a student to take a screen shot of the final score page at end of level 3 or 6, if you wish to see it.

VR Mode:
If playing in VR mode remind students to PULL THE TRIGGER to extend the net.

Overview:
1. Individuals do not evolve, BUT species evolve over generations, this takes time to occur.
2. Over many generations, animals from a particular species may look different from their ancestors, and they are better able to survive.
3. The selection of traits occurs "naturally" because animals cannot change their physical traits, just because they want to, or even because they need to.
4. Change happens because some animals' appearances, or traits, make them better able to survive in a particular environment and to produce more children, or offspring.
5. For example, *mimics*, which are non-poisonous butterflies that have the appearance of poisonous species, are better able to survive because they are less likely to attract predators.
6. In the next generation of a species, there will be more offspring of parents with the successful traits that helped them survive.
7. This also means there will be fewer children, or offspring, of parents with the less successful traits.
8. Evolution happens over several generations, as each set of ancestors pass their genes to the next generation.

Objectives:

1. Understand that there is variability in the traits (appearances) of individual animals within a species (within-species variation).
2. Understand how variability in traits affects the ability of individual animals to survive and reproduce.
3. Understand how within-species variation makes it possible for a species to evolve via natural selection, that is, traits exhibited in a population change over successive generations.
4. A population is the number of organisms of the same species that live in a particular geographic area at the same time, with the capability of interbreeding. (*Note: This is not specifically defined in game*)
5. Via play, figure out how natural selection can bring about wing pattern changes in successive generations of particular species of butterflies.
6. Be able to articulate *why* the butterflies become harder to catch with each level.
7. Understand that each level of play represents changes over many generations.
8. Interact with a bar chart to make predictions about ongoing species survivability (*serves as developmentally appropriate introduction to population dynamics*).

Background: Natural selection is the differential survival and reproduction of individuals due to differences in traits. All populations of animals show variability in the traits that individual organisms express, and this includes humans (e.g., height, hair color, ability to process lactose in adulthood). This is partly due to random mutations in the genome of an individual organism. Children, or offspring, can inherit such mutations, and throughout their lives these changes can interact with their environments to cause variations in the traits that they express, or show.

When individuals with certain variants of a trait survive and reproduce more than individuals with less successful traits, then the frequencies with which the successful heritable traits appear will change over generations. In this way, a population of many individuals evolves and changes over time. The more successful traits are seen more often.

Natural selection acts on the **phenotype, or the observable characteristics or traits of an organism**, but it is the genetic (heritable) part of any phenotype that gives a reproductive advantage to an organism. An important concept in natural selection is that there is **no intentional choice**. In artificial selection, certain traits are purposefully and intentionally bred for; organisms may be selectively mated to select for those traits.

Features of **mimicry give individual animals a reproductive advantage (e.g., by allowing them to avoid predation or being eaten). This enables the animals that survive to leave more offspring (children),** on average, than other members of the same species which were not as successful. In this game, success is defined by how well the surviving non-poisonous butterflies resemble the poisonous butterflies. Those children of the successful butterflies have a greater chance of passing on the more successful wing patterns to their offspring.

Concepts/ Vocabulary (*Optionally* – use these terms to create a pretest and/or posttest**):**

1. Species
2. Traits
3. Environment
4. Offspring
5. Generation
6. Phenotype (*Not defined in game*)
7. Intention

Potential Lesson Structure:

1. Group lecture: Introduction of concepts and vocabulary.

2. Gameplay: Students play *Catch A Mimic* on a platform of the teacher's choice. It is designed for individual play, though others can certainly watch.

3. Worksheet/Test (*optional*): Students can complete a vocabulary worksheet and answer open-ended questions, e.g., What is mimicry? Does it happen in one generation? *Why* are the non-poisonous harder to spot over time?

4. *'What I learned'* Post-Game Discussion: Return as a whole group, or in small groups, to discuss the answers to the worksheet and the takeaway from the gameplay. Be sure and go over the interactive bar chart and why students made certain decisions. Figure 1 shows the bar chart, which appears at the end of levels 2 and 5. The students get three chances before the game animates the correct answer.

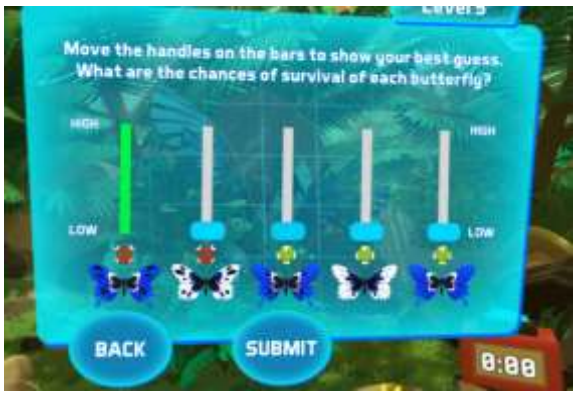

Figure 1 Interactive Bar Chart - Intro to Population Dynamics

Main lesson- Level = 4th/5th grade:

a. SPECIES

Ask students to call out some different kinds of animals.
Different kinds of animals are different SPECIES.
A SPECIES is a group of animals that are very similar, and these animals reproduce to have OFFSPRING.

b. OFFSPRING

OFFSPRING are the babies that make a new generation of animals that are of the same SPECIES as their parents. (For younger children continue with the following)

Are butterflies the same kind of animal as X or Y? [No]
Do butterfly parents have butterfly OFFSPRING? [Yes]
Do butterfly parents have X or Y OFFSPRING? [No]
But...there are also different kinds of butterflies.
Can you name some? What are some colors you have seen?

(Show pictures.) Monarchs and Blue Morphos are different SPECIES of butterfly. Each of these butterflies has OFFSPRING that look like them, and not like these other kinds of butterflies.

c. TRAIT

How are some butterfly SPECIES different? (Show pictures)
Have students list the ways in which the species differ: size, shape, color, placement of spots and splotches.
Each of these is a TRAIT. A TRAIT is something like a characteristic that all animals in a SPECIES have, and TRAITS are often different between SPECIES.

TRAITS are important because they help animals to survive. Remember that OFFSPRING look like their parents.

That is because OFFSPRING have traits like their parents. For example, tall children often have tall parents, too. Traits are observable characteristics.

d. **ENVIRONMENT**

The ENVIRONMENT is the place in which animals from a species live.
The ENVIRONMENT is the geography, the weather, the plants around them, and the other animals that may try to eat them, or be eaten by them.

e. **FITNESS**

The FITNESS of an animal is defined by how good it is at surviving in its ENVIRONMENT.
TRAITS should help an animal to survive in its ENVIRONMENT.
Better TRAITS make an animal more 'FIT' for its ENVIRONMENT.
So, with better TRAITS an animal has better FITNESS.

Does a fish survive well in a river? [YES]
But, would a fish survive well in the desert? [NO]
Does a mountain goat survive well in the mountains? [YES]
But, would a mountain goat survive well in the ocean? [NO]

What are some other animals that wouldn't survive well in a different ENVIRONMENT? Your turn to make up some weird ones!

f. **VARIABILITY**

OFFSPRING have the same TRAITS as other animals of their SPECIES, but their traits are always a little bit different, too.

Babies usually look more like their parents than other people. But, babies always are also a little bit different from their parents.

VARIABILITY means that different animals have TRAITS that are always a little bit different from other animals from their same SPECIES.

Zebra Example.
What SPECIES are these animals? [Zebras- show picture, attached]

They all look similar, don't they? That is because they all have similar TRAITS because they are from the same SPECIES.

But if you look carefully, they all look a little bit different, too.
Look at the black and white stripes on the back of their legs, on their haunches. The stripes do not look exactly the same, do they?

It is the same with humans, some are taller, and some are shorter.
We're all people, and we have the same traits, but we're all a little bit different, too.

It is the same with the butterflies you will see. Animals of the same SPECIES have the same traits,
But their TRAITS are also always a little bit different, and this is called VARIABILITY.

Sometimes, two animals of the same SPECIES will have versions of a TRAIT, but one animal's version will have better FITNESS than the other animal's version.
This can allow them to be more successful and survive to have children.

For example, two Zebras may both have stripes, but one animal's stripes may have a pattern that is a more successful TRAIT than the other animal's stripes, given the environment.
Why do you think Zebras have stripes in the first place? [1]

g. Intentionality

The *Catch A Mimic* game stresses that many generations must pass before a noticeable change in the populations' patterns can be detected.

During the post-play group discussion be sure and highlight that the butterflies have no INTENTIONALITY. They do not "intend to change". They do not look around and say to themselves, "Hmm, it seems the ones with black stripes are living longer", and then decide to give themselves black stripes.

1.Answer - The stripes may cause optical illusions that make it harder to make sense of which directions the animals are moving. In addition, this optical illusion may help the Zebras avoid insects that bite them and carry disease.
(i) https://en.wikipedia.org/wiki/Zebra#Stripes
(ii) https://en.wikipedia.org/wiki/Barberpole_illusion
(iii) https://en.wikipedia.org/wiki/Wagon-wheel_effect

A change in phenotype (the typical way a species looks) takes time, and many generations of offspring, for the mimicking pattern to emerge. This occurs because of the variability in the surviving population and rates of reproduction.

Insect species are a great way to understand the evolutionary mechanism of natural selection, because generations come and go much faster than in the human population.

End Lesson Section

Acknowledgments:
Made with a variety of funds, primarily NSF AISL grant #1423655.

Special thanks to James Comstock and Tyler Agte.

The game was inspired by the movie *Amazon Adventure* by SK Films see
http://amazonadventurefilm.com/

for more information on the film, and on the life of Walter Bates.

Appendix: National Next Generation Science Standards - NGSS

These are Middle and High School for

Evolution, Natural Selection and Adaptations.

http://www.nextgenscience.org/topic-arrangement/hsnatural-selection-and-evolution

This topic falls under Life Sciences (LS). MS stands for Middle School. There are several cross-cutting ideas as well embedded like cause and effect.

MS.Natural Selection and Adaptations

Students who demonstrate understanding can:

MS-LS4-1.	**Analyze and interpret data for patterns in the fossil record that document the existence, diversity, extinction, and change of life forms throughout the history of life on Earth under the assumption that natural laws operate today as in the past.** [Clarification Statement: Emphasis is on finding patterns of changes in the level of complexity of anatomical structures in organisms and the chronological order of fossil appearance in the rock layers.] [Assessment Boundary: Assessment does not include the names of individual species or geological eras in the fossil record.]
MS-LS4-2.	**Apply scientific ideas to construct an explanation for the anatomical similarities and differences among modern organisms and between modern and fossil organisms to infer evolutionary relationships.** [Clarification Statement: Emphasis is on explanations of the evolutionary relationships among organisms in terms of similarity or differences of the gross appearance of anatomical structures.]
MS-LS4-3.	**Analyze displays of pictorial data to compare patterns of similarities in the embryological development across multiple species to identify relationships not evident in the fully formed anatomy.** [Clarification Statement: Emphasis is on inferring general patterns of relatedness among embryos of different organisms by comparing the macroscopic appearance of diagrams or pictures.] [Assessment Boundary: Assessment of comparisons is limited to gross appearance of anatomical structures in embryological development.]
MS-LS4-4.	**Construct an explanation based on evidence that describes how genetic variations of traits in a population increase some individuals' probability of surviving and reproducing in a specific environment.** [Clarification Statement: Emphasis is on using simple probability statements and proportional reasoning to construct explanations.]
MS-LS4-6.	**Use mathematical representations to support explanations of how natural selection may lead to increases and decreases of specific traits in populations over time.** [Clarification Statement: Emphasis is on using mathematical models, probability statements, and proportional reasoning to support explanations of trends in changes to populations over time.] [*Assessment Boundary: Assessment does not include Hardy Weinberg calculations.*]

Connections to other DCIs in this grade-band: ***HS.LS2.A*** *(HS-LS4-2),(HS-LS4-3),(HS-LS4-4),(HS-LS4-5);* ***HS.LS2.D*** *(HS-LS4-2),(HS-LS4-3),(HS-LS4-4),(HS-LS4-5);* ***HS.LS3.A*** *(HS-LS4-1);* ***HS.LS3.B*** *(HS-LS4-1),(HS-LS4-2),(HS-LS4-3),(HS-LS4-5);* ***HS.ESS1.C*** *(HS-LS4-1);* ***HS.ESS2.E*** *(HS-LS4-2),(HS-LS4-5);* ***HS.ESS3.A*** *(HS-LS4-2),(HS-LS4-5);* ***HS.ESS3.C***
Articulation of DCIs across grade-bands: ***MS.LS2.A*** *(HS-LS4-2),(HS-LS4-3),(HS-LS4-5);* ***MS.LS2.C*** *(HS-LS4-5);* ***LS3.A*** *(HS-LS4-1);* ***LS3.B*** *(HS-LS4-1),(HS-LS4-2),(HS-LS4-3);* ***MS.LS4.A*** *(HS-LS4-1);* ***MS.LS4.B****(HS-LS4-2),(HS-LS4-3),(HS-LS4-4);* ***MS.LS4.C*** *(HS-LS4-2),(HS-LS4-3),(HS-LS4-4),(HS-LS4-5);* ***MS.ESS1.C*** *(HS-LS4-1);* ***HS.ESS3.C*** *(HS-LS4-5)*

The game directly addresses

2 Anatomical similarities

#4 Genetic variations and survival

#6. Some aspects of proportional reasoning (so math teachers may like this as well)

The High School standards are below:

HS.Natural Selection and Evolution

Students who demonstrate understanding can:

HS-LS4-1. **Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence.** [Clarification Statement: Emphasis is on a conceptual understanding of the role each line of evidence has relating to common ancestry and biological evolution. Examples of evidence could include similarities in DNA sequences, anatomical structures, and order of appearance of structures in embryological development.]

HS-LS4-2. **Construct an explanation based on evidence that the process of evolution primarily results from four factors: (1) the potential for a species to increase in number, (2) the heritable genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for limited resources, and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment.** [Clarification Statement: Emphasis is on using evidence to explain the influence each of the four factors has on number of organisms, behaviors, morphology, or physiology in terms of ability to compete for limited resources and subsequent survival of individuals and adaptation of species. Examples of evidence could include mathematical models such as simple distribution graphs and proportional reasoning.] [*Assessment Boundary: Assessment does not include other mechanisms of evolution, such as genetic drift, gene flow through migration, and co-evolution.*]

HS-LS4-3. **Apply concepts of statistics and probability to support explanations that organisms with an advantageous heritable trait tend to increase in proportion to organisms lacking this trait.** [Clarification Statement: Emphasis is on analyzing shifts in numerical distribution of traits and using these shifts as evidence to support explanations.] [*Assessment Boundary: Assessment is limited to basic statistical and graphical analysis. Assessment does not include allele frequency calculations.*]

HS-LS4-4. **Construct an explanation based on evidence for how natural selection leads to adaptation of populations.** [Clarification Statement: Emphasis is on using data to provide evidence for how specific biotic and abiotic differences in ecosystems (such as ranges of seasonal temperature, long-term climate change, acidity, light, geographic barriers, or evolution of other organisms) contribute to a change in gene frequency over time, leading to adaptation of populations.]

HS-LS4-5. **Evaluate the evidence supporting claims that changes in environmental conditions may result in: (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species.** [Clarification Statement: Emphasis is on determining cause and effect relationships for how changes to the environment such as deforestation, fishing, application of fertilizers, drought, flood, and the rate of change of the environment affect distribution or disappearance of traits in species.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Analyzing and Interpreting Data
Analyzing data in 9–12 builds on K–8 experiences and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.
- Apply concepts of statistics and probability (including determining function fits to data,

Disciplinary Core Ideas

LS4.A: Evidence of Common Ancestry and Diversity
- Genetic information, like the fossil record, provides evidence of evolution. DNA sequences vary among species, but there are many overlaps; in fact, the ongoing branching that produces multiple lines of descent can be inferred by comparing the DNA sequences of

Crosscutting Concepts

Patterns
- Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. (HS-LS4-1),(HS-LS4-3)

Cause and Effect
- Empirical evidence is required to differentiate between cause and correlation and make claims

2 – variation due to sexual reproduction, competition and proliferation of the fittest

#3 - Shifts in distributions

#5 - Ability to evaluate and in the role of predator be able to change the environment over time so that one species becomes extinct (the members of the butterfly family that fail to morph and mimic the poisonous butterflies fail to reproduce over time).

Also stated as:

B1. Inquiry, reflection, and social implications

B1.1 Scientific inquiry

B3. Interdependence of living systems and the environment

B3.4 Changes in ecosystems

B3.5x Environmental factors

B4. Genetics

L4.P2 Heredity and environment

B4.4x Genetic variation

B5. Evolution and biodiversity

B5.3 Natural selection