

Classroom Embedded Assessment [CEA] Title: Guppy Color Variation

a. Targeted Performance Expectation(s)

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.]

UNIT: Biological Evolution: Unity and Diversity

Supplemental Information about Targeted Performance Expectation

b. Learning Goal(s)

1. Learners will **develop a claim** that answers the research question: What caused these trends in coloration of guppies?
2. Learners will **identify and describe evidence** related to trends in guppy coloration:
 - physical characteristics of each pool location
 - Turbidity of water
 - Predators
 - Proportions of colorations and genders
3. Students use **reasoning** to connect the evidence to scientific principles about how natural selection provides a mechanism for species to adapt to changes in their environment, including the following elements:
 - Biotic and abiotic differences in ecosystems contribute to changes in expressed traits over time through natural selection.
 - Over time, this process leads to a population that is adapted to a particular environment by the widespread expression of a trait that confers a competitive advantage in that environment.

c. Instructional Context

This CEA would be administered mid-unit, after students have had several experiences and conversations about natural selection. In particular, they should have been introduced to the key distinction between populations adapting over time vs. the misconception that individual animals ‘choose’ an adaptation based on environmental pressures. This CEA is designed to elicit if students are able to use multiple sources of evidence to reason about a particular phenomenon.

d. Student Task/Prompt – *see end of document for copy of handout distributed to students*

Scenario/Phenomenon:

Scientist noticed color variation in guppies from different locations in the same stream (based on actual data). *Research question these scientists are trying to answer: What caused these trends in coloration of guppies?*

Overall structure used to guide this student task (an example of a content-independent structure that may be useful for other scenarios/phenomena in this unit):

Ask students a series of sequenced questions:

Describe a phenomenon to students then

Ask students to articulate or construct a claim about that phenomenon, and

Identify evidence that supports the claim, and

Identify scientific principles (reasoning) that connect each piece of evidence to the claim.

*Connection between task and PE: Describe a phenomenon to students along with some related qualitative or quantitative data/observations, then ask students to produce an explanation about the mechanism for the phenomenon using their interpretation of the data as evidence. **NOTE: could choose to emphasize with students the distinction between “data” (which is something available – e.g. numbers, pictures, descriptions of what happened, and “evidence” which requires the human brain to interpret the data in the context of the problem. Data by themselves don’t necessarily give all the information needed – your brain needs to process the data into ‘evidence’)***

- ***See Student Task Sheet at end for details of the phenomenon presented to students.***

e. Success Criteria

Exemplary student response - See pages after the one-page student handout for hypothetical student responses across range of weak → strong.

Claim

Strong: A concise response that accurately answers the research question without irrelevant information.

Evidence

Strong:

- A. Includes reference to 5 or 6 variables (1) proportion of bright males; (2) predators; (3) physical barriers – dam & waterfall; (4) deep/shallow; (5) turbidity; (6) females all drab
- B. Evidence includes specificity (e.g. specific proportions rather than “more/less”, where barrier is, how turbidity is related to proportion of bright males, etc.) when citing specific meaningful relationships between variables

Moderate:

- A. Includes reference to at least 3 variables
- B. Evidence includes specificity in terms of meaningful relationships between variables for at least some of the identified variables

Weak:

- A. 2 or fewer variables referenced in evidence... OR...
- B. Lack of specificity about the evidence

Reasoning

Strong:

- A. Describes how natural selection process happens in connection with at least 4 of the evidence pieces, and includes how the observed outcome would result from this process over generations. This description is done in the context of the scenario, using specific pieces of evidence. *NOTE: reference to phrase “natural selection” without explaining the actual process in this particular case would NOT satisfy this criterion.*

Partial example might include: Bright males tend to be successful at attracting females to mate with, unless that trait causes them to be easily seen and eaten by predators. If there is a physical barrier, such as a waterfall, that minimizes predators then the advantage of male brightness will be passed on to successive generations, leading to a high proportion of males being bright as in pool 4. However, in high-turbidity water such as pool 1, the brightness is less effective at attracting mates and would make the bright males easier to see and be eaten by predators, so in pool 1 the trait of male brightness would tend to lead to low success at reproduction and over time few males would be bright in pool 1.

- B. Avoids suggesting that “guppies choose their color” or otherwise implies that individual organisms are making intentional choices

Moderate:

- A. Describes how natural selection process happens in connection with at least 2 of the evidence pieces, and includes how the observed outcome would result from this process over generations. *NOTE: reference to phrase “natural selection” without explaining the actual process in this particular case would NOT satisfy this criterion.*
- B. Avoids suggesting that “guppies choose their color” or otherwise implies that individual organisms are making intentional choices

Weak:

- A. Does NOT explain natural selection (even if term is used) in connection with any of the evidence.
- B. Might (or might not) also include the notion that individual guppies ‘choose’ their color based on circumstances.

f. Next Instructional Steps

Depends on student response patterns. Likely challenges for some students (depending on prior experiences) on which next steps could focus for those students struggling:

- Using proportions of bright/drab males instead of raw numbers. Provide experiences where more numbers may not mean higher proportion (e.g. 50 bright/50 drab vs. 10 bright/3 drab) to underscore this point.
- Processing the many potential variables. Suggest students take one at a time.

- Concept of brightness as attraction for mates (draw comparisons to other species such as birds – e.g. peacocks). Ideally should have been part of unit prior to this CEA.
- Able to write/articulate evidence (need to connect numbers to why important). Suggest maybe a bulleted format (such as in examples below) as a way to take one point at a time and write a short sentence about that piece of evidence. Can help avoid becoming overwhelmed.
- Able to write/articulate reasoning. Suggest maybe using the bulleted list of evidence and put that into ‘paragraph form’ so that their earlier thinking guides the production of a well-reasoned argument. Suggest they incorporate specific detail (such as proportions of bright males) along with more general claims.
- Perhaps have the class generate a list of “tips” for communicating evidence and another for communicating reasoning (see points above). Put on poster that stays in the room for use throughout the year. Add to the list as future experiences suggest additional tips (so that this becomes a collective repository and scaffold to support student abilities).

g. Student Work Samples

See hypothetical student responses (categorized as *strong*, *moderate*, or *weak*) in pages following the student handout

h. Reflection and Revision

None

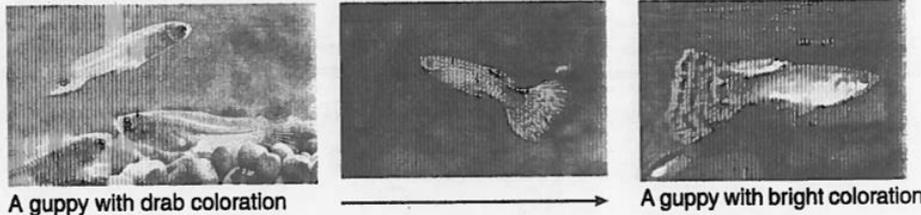
NOTES: *Student handout begins on next page*

Hypothetical student responses (across range weak to strong) appear after handout

Guppy Color Variation

When biologist John Endler began studying a species of wild guppy (*Poecilia reticulata*) in the 1970s, he was struck by the wide color variation among guppies from different streams and sometimes even among guppies living in different parts of the same stream. Guppies from one pool sported vivid blue and orange splotches along their sides, while those farther downstream carried only modest dots of color near their tails. The pictures in Figure 2.1 show how the coloration of guppies can range from drab to bright.

Figure 2.1. Color Variation in Venezuelan Guppies



Endler photographed hundreds of guppies and carefully measured their size, color, and the placement of their spots. He began to see a pattern where guppies lived in a particular stream and whether the fish were bright or drab.

This led him to wonder: **What caused these trends in the coloration of the guppies?**

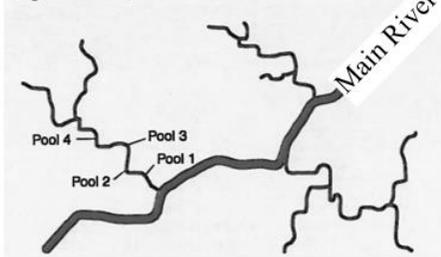
- Student Task**
Answer the question posed by providing:
- claim
 - evidence
 - reasoning

Table 2.1. Information About the Pools Where the Venezuelan Guppies Were Found

Characteristic	Pool			
	1	2	3	4
Type	Deep (at a bend in the stream)	Deep (above a natural rock dam)	Shallow (at a bend in the stream)	Deep (above a 6 ft. waterfall)
Pool location (see Figure 2.3)	50 m upstream from the river	100 m upstream from the river	150 m upstream from the river	200 m upstream from the river
Turbidity of water (NTU)	Ranges between 27.50 and 36.25	Ranges between 8.75 and 27.50	Ranges between 3.00 and 8.75	Ranges between 3.00 and 8.75
Predatory fish in the pool (total)	28	15	6	0
Predators	Cichlids	12	0	0
	Rivulus	6	10	6
	Acara	10	4	0
Guppies found in the pool (total)	102	165	187	231
Bright males	5	50	76	108
Drab males	41	19	10	5
Bright females	0	0	0	0
Drab females	56	96	101	118

Note: Turbidity is the cloudiness or haziness of a fluid. Nephelometric turbidity unit (NTU) range in value from 0 (completely clear) to 50 (no light passes through the fluid)

Figure 2.3. Map of the Pool Locations



Task from:
Sampson, V. & Schleigh, S. (2012).
Scientific Argumentation in Biology: 30 Classroom Activities. Arlington, VA: NSTA Press.

Potential categorization of CLAIMS

CLAIM 1 – Strong *(correct and succinct)*

The variation in guppy color is largely due to the physical characteristics of their pool. *(full points because it identifies the root cause – justifications and rationale to come, including ideally a full list of the physical characteristics)*

CLAIM 2 – Weak *(incorrect even though there is some weak connection to reasonable possibility)*

The variation in guppy color is because predators stir up sediment in the water and add their poop to the mix making it hard to see guppies. *(no credit because this is mostly filler text that suggests this student is reaching for a claim)*

CLAIM 3 – Moderate *(correct but has the root cause unmentioned)*

The variation in guppy color is because predators can get more easily to some pools than others. *(partial credit because this is not the ROOT CAUSE but rather a consequence of it. Not incorrect, but weaker than strongest answer)*

CLAIM 4 – Moderate *(correct but incomplete)*

The variation in guppy color is because of the turbidity of the water. *(partial credit because this is a part of the reason but not all of it)*

CLAIM 5 – Strong *(correct with a little extra but not yet necessary detail)*

The variation in guppy color is largely due to the physical characteristics of their pool because it affects which predator can get where. *(full points because it identifies the root cause – it happens to also have a brief justification which is correct, which is OK but not necessary. IF however that brief limited justification were incorrect, then it would have lost some of the points).*

CLAIM 6 – Weak *(incorrect)*

The variation in guppy color is because of the distance of the pool from the main river.

Potential categorization of EVIDENCE

EVIDENCE 1 – Moderate (3 or 4 variables referenced, with some specificity)

- When the pools are high turbidity, there tends to be a lower proportion of bright males.
- When a physical barrier such as a waterfall (before pool 4) is present, that blocks predators and as a result a higher proportion of males are bright.
- The farther a pool is from the main river, the more challenging it is for predators to get there.

EVIDENCE 2 - Weak

- Predators eat the guppies
- Bright males like to swim farther away from the main river
- Bright females are always eaten by predators

EVIDENCE 3 – Strong

- Low turbidity water in pools 3 & 4 have larger proportions of bright males (88% in pool 3, 96% in pool 4)
- Physical barriers such as a rock dam (before pool 2) and a waterfall (before pool 4) tend to limit the number of predators that can get past them.
- Since all females are drab in all pools, the trait of “brightness” for females is not related to any of the pool variables such as turbidity, presence of physical barrier, deepness, etc.
- The deepness of a pool does not seem to be strongly related to proportion of bright males by itself, since some predators are present in both deep and shallow pools.

EVIDENCE 4 – Moderate

- A waterfall seems to stop predators (pool 4) and a rock dam (pool 2) seems to block at least some predators, and more bright males are present when there are fewer predators.
- Drab males seem to prefer deep water, unless that water is also low turbidity.
- Low turbidity water seems to give a greater advantage to bright males.

Potential categorization of REASONING

REASONING 1 - Strong

Females tend to want to mate with bright males, as evidenced by larger proportions of bright males whenever there are fewer predators around. This leads to offspring that tend to also be brighter (if they are male) which over time leads to a high proportion of bright males in the population. However, when there are high numbers of predators, such as in pools 1 and 2, then male brightness is a disadvantage because predators can see them more easily and eat them, meaning that those bright males would no longer be available to reproduce, which eventually leads to fewer bright males in the population. When there are natural barriers to predators, such as the waterfall at pool 4, the lack of predators means that male brightness is universally advantageous and eventually nearly all males will be bright, as shown by the 96% ratio (108/113) of bright males in pool 4. The higher turbidity pools (pool 1 especially, and pool 2 a little) may also reduce the advantage of male brightness for mating because it would be harder for females to see them, and combined with the disadvantage of brightness making it easier for predators to see them, over time fewer and fewer bright males in pools 1 and 2 would reproduce, and eventually the trait of male brightness would become more rare, such as the 11% (5/46) bright males in pool 1.

REASONING 2 - Weak

When males notice that there are no predators around, like in pool 4, most of them become bright so that they can attract females. However, if the water turbidity goes up, like in pools 1 and 2, many of the males would become drab so that they can blend in and avoid detection by predators. This process is called natural selection, because some traits of guppies are naturally selected for, or selected against, based on the conditions the guppies find themselves in. Since conditions naturally vary, from deep pools to shallow pools, from lots of predators to few predators, from waterfalls to calm pools, then the variation in traits will be expressed to take best advantage of whatever situation they find themselves in. The females don't have this same natural selection because they are all drab and stay that way, which suggests that the predators don't like to eat the females and so they don't have to worry about that.

REASONING 3 - Strong

The process of natural selection means that, over time, certain traits will tend to be reproductively successful while others will not. Which traits will be reproductively successful – that is, which traits will tend to be passed on down to offspring and become more common over time – depends on the set of circumstances a particular species finds itself in. In this guppy situation, when there is low turbidity (like in pools 3 and 4) and few predators, the trait of male brightness will tend to draw female mates and thus be reproductively successful, leading to higher proportions of bright males over time. However, in turbid waters like pool 1, that brightness won't be as much of an advantage because the females can't see them, and in addition any bright males in pool 1 are more likely to be seen and eaten by predators. So in pool 1, male brightness is not an advantage (females can't see it) and it IS a disadvantage (predators will eat you), so over time the offspring that survive and reproduce in pool 1 tend to be drab males and NOT bright males.