Level up: Capturing upper-division student understanding of natural selection

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V O I F P

Natural selection is a principle mechanism of evolution[1]

- A complete understanding of natural selection includes five key concepts
- Using these concepts of natural selection, the Concept Inventory of Natural Selection[1] (CINS) and Bishop & Anderson Open Response Instrument[2] (ORI) assess student knowledge related to natural selection
- The CINS and ORI are documented as valid and reliable in introductory courses; their utility in upper division courses is unknown

What can upper-division biology instructors learn by using the CINS and ORI?

- Do the CINS and ORI capture change in upper division student understanding of natural selection?
- On the ORI, do students perform similarly across questions?
- Do the ORI prompts evoke more or different alternative conceptions?

Key Concepts

- Variation within a Population
- Origin of Variation
- Inheritance
- Fitness
- Change in a Population

CINS Question: A typical natural population of guppies consists of hundreds of guppies. Which statement best describes the guppies of a single species in an isolated population?

A. The guppies share all of the same characteristics and are identical to each other.
B. The guppies share all of the essential characteristics of the species; the minor variations they display don't affect survival.
C. The guppies are all identical on the inside, but have many differences in appearance.
D. The guppies share many essential characteristics, but also vary in many features.

ORI Student Response to Prompt: *Since cave salamanders lived in the dark for many years, a mutation happened in one of the salamanders that made it lost its vision. Since it did not affect much because they live in a cave, this was passed to its offspring and with time it ended up increasing in the population.*

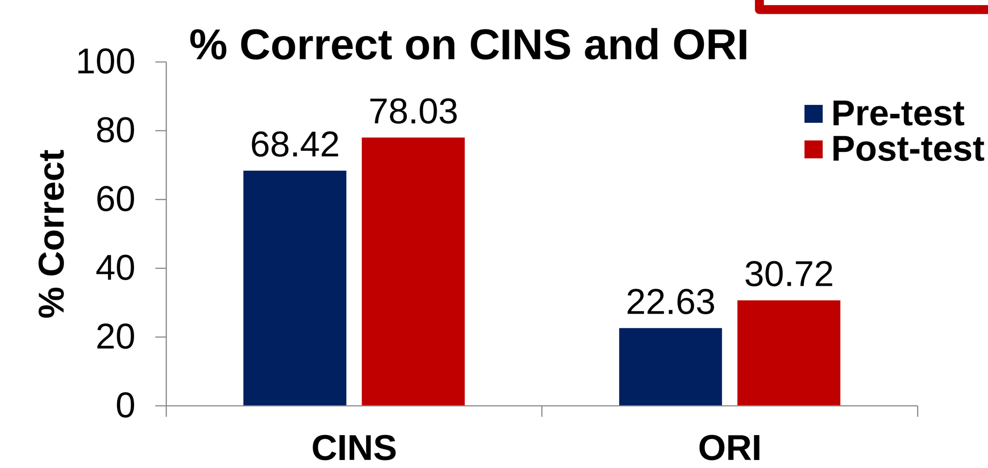
In an upper-level biology course, students (n=76) completed the CINS and ORI

- Two sections of learner-centered evolutionary biology course (Fall 2012, Spring 2014) taught by the same instructor
- Mean GPA = 3.26 ± 0.56 (SD)
- Students were assessed online pre, post instruction using CINS and ORI
- All assessments were graded

	CINS	ORI
Assessment Style	Multiple choice	Short answer
Number of Questions used for comparison	10 out of 20	2 out of 6

- CINS features 10 key concepts of natural selection, we focused on 5 (see above)
- CINS was not reliable
  - Pre-test reliability: 0.765
  - Post-test reliability: 0.694
- ORI coded using modified Bishop and Anderson coding rubric[3], IRR = 87%
- Alternative conceptions coded using Nehm Lab coding rubric[4], IRR = 88%

Does assessment style matter?



- There is a significant pre to post test difference on both CINS (t=4.296, df=75, p=0.000) and ORI (t=3.527, df=75, p=0.001)
- In addition, students perform significantly higher on the pre and post test CINS over the ORI (F=25.564, df=75, p=0.000)

- Students score high on the CINS and very low on the ORI
- Students may be gaming the CINS
  - Key words are recognizable to upper division students
  - Distractors do not activate alternative conceptions
- For both the CINS and ORI, the normalized change score were low (less than 0.40)
- The CINS does not appear to capture upper-division student learning of evolution

Assessment	Normalized Change Score*	SD
CINS	0.34	0.45
ORI	0.00	0.39

*Normalized change scores are statistically different (t=5.46, df=65, p=0.000)

How do students perform across questions within the ORI?

1. Cheetahs are able to run faster than 60 miles per hour when chasing prey. How would a biologist explain how the ability to run fast evolved in cheetahs, assuming their ancestors could only run 20 miles per hour? (Trait gain)

Selection favored cheetahs that could run fast (V) and catch their prey to eat and survive (F), therefore they became more abundant in the population (P).

2. Cave salamanders are blind (they have eyes which are nonfunctional). How would a biologist explain how blind cave salamanders evolved from sighted ancestors? (Trait loss)

A population moved to a cave where sight (V) was not a selected trait. Salamanders with poorer sight had more energy to find food, they reproduced more (F). Salamanders with poor sight had offspring with poor sight.

Mean score across key concepts

	V	O	I	F	P
Cheetah	56.00%*	9.21%	32.89%	50.66%*	30.26%
Salamander	59.00%**	13.82%	13.82%	21.71%	20.39%

Student scores on each key concept is dependent on the prompt (X^2=14.46, df=4, p=0.006)
*Students score significantly higher in V and F in the trait gain prompt
**Students score significantly higher in V in the trait loss prompt

- Students perform differentially on the ORI
  - The mean score of the cheetah prompt (M=35.79, SD=18.85) is higher than the salamander (M=25.66,SD=21.06) prompt
  - Students are more likely to discuss inheritance and fitness on the cheetah prompt than on the salamander prompt
  - For both prompts, students are unlikely to include origin of variation in their response (O)
- The differences in student responses may be the result of prompt structure: trait gain versus trait loss

Do trait loss or trait gain evoke different alternative conceptions for students?

Alternative Conception	Explanation[3]	Example from student response
Pressure	Compelling force causing change to occur rather than an environmental factor that allows for differential survival	*As prey evolved to become faster to outrun the predator, the predator in turn evolves to become faster to catch the prey*
Adapt	Adjusting or acclimating oneself to new or circumstances, making oneself more fit; opposed to a heritable trait that increases survival and reproduction relative to other individuals	*The salamanders use other senses that are better adapted to cave life*
Need	Need is the cause for evolutionary change	*The cheetah needed to run faster to catch its prey*
Must	Organism required to change in order to survive	Must refers to desire for that to happen*
Use/Disuse	If organism does not use trait it disappears	*Over time the cave salamander did not use its eyes so there was no benefit to having them*
Energy	Organism chooses to allocate energy in other areas to make itself more fit	*There was a tradeoff between sight and another, more important trait for cave dwelling salamanders*

Pre-test	Cheetah	Salamander
P	**84%**	15%
A	21%	34%
N	13%	**47%**
M†	0%	0%
U	0%	**27%**
E	0%	**31%**

Post-test	Cheetah	Salamander
P	**97%**	22%
A	2%	**16%**
N	7%	**34%**
M†	0%	0%
U	0%	**34%**
E	0%	**45%**

- Prompt structure matters
  - The cheetah prompt (trait gain) elicits pressure
  - The salamander prompt (trait loss) elicits need, use/disuse, and energy
- Despite instruction students still evoke many alternative conceptions on the post test

Recommendations for instructors

- Students score high on the CINS pre-test, making it less useful than the ORI in an upper-division course
- The ORI allows students to construct a response, providing a richer reflection of upper-division student understanding of natural selection
- We recommend instructors use both the cheetah and the salamander prompt to fully capture student understanding
- Further research should utilize larger populations of upper-division biology students to determine CINS reliability

Literature Cited
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