Scaffolding the Conceptual Underpinnings of Evolution in 2nd & 3rd Grade

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Research funded by the NSF
Learning Progressions

“Learning progressions are descriptions of successively more sophisticated ways of thinking about a topic that can follow one another as children learn about & investigate a topic over a broad span of time (e.g. 6 to 8 years).

They are crucially dependent on instructional practices if they are to occur.”

NRC *Taking science to school*
How to frame base (2-3rd grade) of an evolution LP?:

Design Problem

Taking science to school LP design principles:

1. In conceptualizing the beginning of the LP, strategically capitalize on understandings children bring to the classroom.

2. Leverage understandings in systematic knowledge-building across the progression.

3. Over the course of LP, integrate 4 strands of scientific literacy.
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- Know, use and interpret scientific *explanations* of the natural world.
- Generate and evaluate scientific *evidence and explanations*.
- Understand the nature and development of scientific knowledge.
- Participate productively in scientific practices and discourses.

*NEED EXPLANATORY POWER AT EVERY GRADE.*
Principles underlying our design of 2nd-3rd Evolution Learning Progression

_Taking science to school_ design principles +

1. Design the learning progression to provide explanatory power at each grade level.

2. Focus the learning progressions on increasingly powerful explanations of the fit between organisms & their environment.

3. Keep explanatory power + Reduce challenge for young kids by limiting focus to biological systems at the level of organisms, populations of organisms & their environment, & change at the level of microevolution.
2nd /3rd Grade microevolution focus also strategic for addressing key bugs

• Foregrounding of phenomenology of populations
  – Supports representation of variation
  – Decreases tendency to reason in terms of types or essences

• Foregrounding changes in environmental conditions & corresponding changes in survival value of traits
  – Supports interpretation of value of traits in relation to environment as opposed to some ideal form
“With the environment changing incessantly, natural selection… never commits itself to a future goal.”

Ernst Mayr
1. Organisms live where they belong

2. Organisms live where they can get their needs met

3. Variation in structures/ Limiting factors
   Organisms live in all kinds of places, with different limiting factors. Differences in the same structure help organisms get what they need where they live.

4. Survival value of a species' traits
   A species' traits typically have some survival value. A way to try to understand a trait is to consider how it might help these organisms survive and have offspring that survive.

5. Within-population variation & differential survival value
   Even individuals of the same species living in the same place are not the same. These differences can matter for which individuals have the best chance to survive & have offspring that survive.

6. Over many generations, inherited traits that help organisms' chance to survive & reproduce become more common. Those that hurt its chances become less common.

7. Organisms adapted to where they live
   This process of natural selection leads to organisms that are adapted to where they live.

Toward a Basic Understanding of Inheritance

Explanations of Fit Between Organisms & Where They Live
Pedagogical principles underlying instructional design

1. Develop children’s understanding of the ideas through engineering contexts in which they *use* the ideas in problem-focused scientific knowledge-building practices.

2. Build knowledge of the phenomenology & puzzles therein before explanation thereof.

3. Leverage strategically selected in-depth cases of the phenomenology as a basis to build generalizations and abstractions.
Principles for choosing cases 2nd/3rd grade

1. Variability of traits & changing environmental press relatively transparent.

2. Bugs less likely to be evoked

3. Include linked contrast cases of natural selection & artificial selection.
Design

Students
  - Urban, mostly low income, multi-ethnic
  - Total $n=180$

Approximately half participate over a 2-year span: 2nd - 3rd grade

2-yr span children revisit conceptual terrain in a second domain
  - Animals & their behavior
  - Botany

Two kinds of sites:
  - Summer school program
  - Public school classrooms
Early Investigation:
Prediction, tracking & analysis of within-kind variation

1) Predict: Will these Brassica rapa Fastplant seeds will grow up to look just the same? If not, why not? How do we think they will be different? Sources of the difference?

2) Each child plants seeds in 8 pots & observes closely over time to consider how they are different.

3) Class builds table of traits & characteristics, on basis of observations.

4) Children collect data on emergent characteristics.
Thought Experiment Research Preferences

*Draw a line between the environmental change and the trait that you'd like to research. Put a (1) next to your first choice, a (2) next to your second choice and a (3) next to your third choice.*

<table>
<thead>
<tr>
<th>ENVIRONMENTAL CHANGE</th>
<th>CHARACTERISTIC: (Trait)</th>
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- **COLOR:**
  - (Green – Yellow – Purple)

- **HAIRINESS:**
  - (Hairy – Hairless)

- **DAYS TO FIRST FLOWER:**
  - (days)

- **HEIGHT OF FIRST FLOWER:**
  - (height – cms)

- **NUMBER OF FLOWERS:**
  - (flowers)

Sheep arrived and began eating the plants.

Caterpillars arrived and began eating the plants.

Tree canopy grew and blocked most of the sunlight.

Bees got sick and there weren’t as many bees to pollinate the flowers.
Part I: How are these aster seeds different from each other?
What trait do you think would help aster seeds travel far on the wind?

Part II: Design of experiment to test prediction.
Part 3. Empirical Investigation
Part 4. Thought experiment  (Cody & Overton, 1996)
A storm blows some of these aster seeds out to sea. Some land on an ocean island.

The seeds that landed on the island looked like this:

Generation 1

The seeds these plants produced looked like this:
Predict how distribution of seed traits on the island would change across subsequent generations

Predict distribution in *next* generation

Predict distribution after *many* generations on the island

Explain what trait you think would be a survival advantage & why.

Compare your predictions to what the scientist saw.
What I think will happen is most of the heavy seeds will fly on the island and most of the light seeds will fly to the water. Because the heavy seed won’t travel that far and the light seed would fly too far to reach the island.
1. Organisms live where they belong

2. Organisms live where they can get their needs met...

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Some likenesses between parents & offspring are inherited. Some are not.

(Variant of 3rd-5th AAAS)

Offspring are very much alike, but not exactly like their parents & one another. (K-2 NRC)

Organisms go through a cycle of growth & development, reproduction, & dying of the older generation.

Toward a Basic Understanding of Inheritance

Explanations of Fit Between Organisms & Where They Live
From study of *Brassica rapa* traits to Microevolution thought experiments

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How might the sickness of some bees affect the height of the first flower in future generations?

**Environmental Change:**
We are studying what we think would happen to the Brassica plants if there were some bees that get sick so there weren’t as many bees to pollinate the flowers.

**Survival Value of Trait:**
We think that Brassica that are tall will have a survival advantage because it will be easier to go down from very high and their flowers will be easier to see. We think Brassica that are short will be less likely to survive because it is harder to get them and see them.
Distribution of Trait in Current Population:
Representation of Brassica trait data

Prediction of Trait in Future Generations:
We think in future generations the Brassica that are tall will be more common because when the bees fly they will see the tall Brassica plants instead of the small. The babies of the babies of the tall plant will probably be tall too. We think the median height will get higher in future generations.
Assessment Instrument

• Instrument development & refinement in collaboration with Mark Wilson

• One-on-one structured interviews, pre & post

• Problems in form of:
  – Predicting what population will look like post environmental change + explain of mechanism (guppies coloration post arrival of predator)
  – Interpretation & explanation of what did happen
  – Explanation of change that already occurred (cheetah speed)

• All based in photographs & /or realistic icons children can manipulate
LP 7 Natural selection as explanation of organisms well adapted to their environment.

LP6 Over many generations, inherited traits that help organisms’ chances of surviving & reproducing become more common

LP 5 Within-population variation & differential survival value

LP4 Survival value of species’ traits

LP3 Structures/ Limiting factors

LP2 Live where they get what they need

LP1 Live where they belong
Preliminary formative analyses
Refining learning progression, based on:

Unanticipated fruitful intuitions /intermediary understandings
- Relatively easy for children to reason about survival value of different traits from perspective of the individual.

Stumbling blocks
- Failure to extend consideration of differential survival value of a trait to impact on chance to successfully reproduce & subsequent influence on distribution of traits in offspring generation
Revisions of learning progression

Fit of organisms & their environment strand
Current work

- Recode all interviews X new progression
- Fine-grained analysis of bugs X context
- Refine curriculum to capitalize on newly identified fruitful intuitions & better address difficulties
- Support classroom teachers to take up the curriculum
- Try to disentangle robust developmental constraints from suboptimal learning opportunities.
“What children are capable of at a particular age is the result of a complex interplay among maturation, experience, and instruction. What is developmentally appropriate is not a simple function of age or grade, but rather is largely contingent on prior opportunities to learn.”

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