Learning Progression Framework and Assessments for Community Ecology: How Students Progress Toward Systems Thinking

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Thanks to:

- **Participating teachers & students**
- **Teachers in Residence** - Marcia Angle, Mitch Burke, Terry Grant, Debi Kilmartin, MaryAnn Murphy, Liz Ratashak, Michael Schiebout
- **Research Collaborators** – Carol Blanchette, Michele Johnson, Shawna McMahon, Johnathon Schramm, Scott Simon, Brook Wilke
- **Student Coders** – Beth Kennicutt, Anthony M., Katrina Marzetta, Trent Smith
- **The National Science Foundation**

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Our Research Question

• How do students reason about ecological disturbance?

• Reasoning requires:
  – Using microscopic processes to link among scales in the hierarchical ecosystem structure.
  – Ability to identify constraints and predict a system’s likely response to disturbance.

• This reasoning ability is important if we expect students to make citizenship decisions that preserve biodiversity and ecosystem function.
Challenges with assessing student understanding of ecosystems

• Ecosystems are complex and contingent
  – Governed by a large variety of principles.
  – Principles vary in importance depending on context.

• Students lack experiences with the natural world
  – Don’t have many experiences.
  – Experiences are geographically constrained.
  – Many students have spent more time watching movies and nature shows than actually being outdoors.
Methods

- Developed 3 scenarios about ecological disturbance
- Administered semi-structured interviews
- Students in rural Michigan, suburban Colorado, and urban Maryland
  - 46 grade 6-12 students
  - 3 undergraduates
  - 4 post-doctoral researchers ecology
Scenario 1: Python Introduction to the Florida Everglades

Native Asia

Florida Everglades

Scenario 1: Python Introduction to the Florida Everglades
Scenario 2: Habitat Fragmentation and Lyme Disease Risk
Scenario 3: Loss of Kelp Forest Habitat
## Explaining Ecosystems and Subsystems

<table>
<thead>
<tr>
<th>Comparison Tasks</th>
<th>Traits of Organisms; Life Cycles</th>
<th>Population Change Over Time and Space</th>
<th>Interactions among Organisms</th>
<th>Interactions among organisms and their environment</th>
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</table>

Black: Linking processes that students at all levels can tell us about  
Green: Upper anchor accounts based on ecological/ systems reasoning  
Red: Lower anchor accounts based on anthropomorphic/ teleologic/essentialist reasoning
Analysis methods

Used grounded theory to look for trends in how students think about:

– How communities are structured
– How individuals, populations, communities, and ecosystems respond to disturbance
Results

Learning Progressions for Environmental Literacy

Learning progression level

Number of Indicators for Type of Reasoning

Hierarchical systems, space and time variability, mechanistic explanations

Actors in settings with anthropomorphic, teleological, and essentialist motivations.
How do you think the Burmese python got to the Florida Everglades?

I think someone smuggled it in their suitcase. Some people do it for drugs. – Caitlin 6th grade

Do you think we might see the python become more abundant in other parts of the US?

They might spread in the south because the weather's pretty. – Sackett 9th grade

Will some pythons not have the new trait after they're in Florida?

Yes. Because they're so used to being from native Asia. So they kind of want to have something to remember that by. – Catlin 6th grade

Is there a way the python can change the population of plants?

No… they're usually a meat eater. Could they change anything about the non-living parts?

Not really. Because it's just there and the python can't wipe it out or get rid of it. – Caitlin 6th grade

Focus on Individual Scale

Direct Interactions Only

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Learning Progressions for Environmental Literacy

Native Asia Florida Everglades

Overly simplistic view of response to change

Learning and adaptation in response to change

How does that happen?

... they grow up to be almost like their parents. I don’t know if it is the traits as much as it is their parents just teaching them as they grow up, like showing them that, if you want to live, you have to be aggressive … - Bobby Middle School

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Attributes of Upper Level Responses

Microscopic to Ecosystem Scale

Rich abiotic description with spatial and temporal variation

Relative strengths of interactions, changes in interactions of life cycle

Indirect and Aggregate effects

Constraints on ability to respond to change

Actions are result of genes X environment, randomness, emergent properties

Functional redundancy

How would you say, using this diagram, that the

So there’s these two sibling sets, one in Burma and one in Florida. Would you expect the traits of the baby pythons born in Burma to be different than the traits of the baby pythons born in Florida? No. I imagine they would be the same … whatever genetics or series of traits that they get from both parents, as well as environmental controls mostly dealing with what resources they’re able to gather. Sam - College
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<th>Description of Interactions</th>
<th>“Why?”</th>
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Discussion

• The majority of the students we interviewed were at the low level or in transition to the middle level.
• We need citizens to be able use systems based reasoning about disturbance, but it is hard.
  • Link microscopic processes to macroscopic events.
  • Understand variability over life cycle, time, and space.
  • Accept randomness as a structuring element.
  • Reason about emergent processes (e.g. collective effects of individuals).
  • Use principles to constrain reasoning
  • Navigate different contexts (i.e. What are the important essentialist characteristics?, Which analogies are appropriate and which analogies are not in a given context?)
Characteristics of the lower anchor

- Communities are hierarchically organized (think Great Chain of Being) and include interspecific and intraspecific relationships (think anthropomorphic) among individuals within the environment (think setting of a play) in which they live.

- Although there is larger community, the focus tends to be on a single organism with anthropomorphic characteristics whose actions tend to be based on free will.

- There is a natural order or balance of nature that governs relationships and each kind of organism has essential characteristics and its place in the natural order.

- Disturbances are disruptions to the natural order and the struggle is to return to the status quo.
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Attributes of Middle Level Responses

**Focus on Populations and Communities**

**Indirect connections among organism**

**Links actions to survival, reproduction, changes in population size, life cycle changes, randomness**

**Organisms can affect environment locally**

**Mechanism for change, but incorrect NS or unconstrained**

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**So here’s a picture of an area that used to be a kelp forest before the sea otters died out. Can you explain the disappearance of the kelp?**

- How do you think the disappearance of the kelp happened? Lillian 9th grade

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**How do you think the introduction of the python has changed this food web?**

- Like some of the underwater plants, you could see them dying off just because the amount of snake traffic that would be going through it and everything. Jack 12th grader

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**How do you think the introduction of the python has changed this food web?**

- The sea urchin, starfish, and larger crabs and other fish populations below them like the sea otters died … then the populations below them like the sea urchin, starfish, and larger crabs and other fish populations because they weren’t being preyed upon …. they’re eating more of the smaller predatory fish. – Joe 7th grader

- Their seeds. The embryos might have traveled over the current … with the current. – Joe 7th grader

- How do you think they got there? Lillian 9th grade

- How do you think the introduction of the python has changed this food web? Jack 12th grader

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**Mechanism for change, but incorrect NS or unconstrained**

**Links actions to survival, reproduction, changes in population size, life cycle changes, randomness**
Characteristics of the Upper Anchor

• Structure of the System
  • Species have central tendencies but are phenotypically and genotypically variable. (contrast to essentialist thinking)
  • Actions of individuals are related to survival and reproduction and are dictated by genetic resources, emergent properties of the system, and stochasticity. (contrast to teleological thinking and anthropomorphic thinking)
  • The environment is hierarchically organized. Matter, energy, and information are important at each scale and can be traced across scale. (contrast to actor within a setting)

• Nature of Change
  • System changes over time and space and has emergent properties. (contrast to “natural order” thinking)
  • Outcome of disturbance is dependent on strength of interactions, genetic resources and plasticity, and relative pace of change among populations (contrast to “returning to balance”)

Conclusions

• The majority of the students we interviewed were at the low level or in transition to the middle level.
• We need citizens to be able use systems based reasoning about disturbance, but it is hard.
  • Link microscopic processes to macroscopic events.
  • Understand variability over life cycle, time, and space.
  • Accept randomness as a structuring element.
  • Reason about emergent processes (e.g. collective effects of individuals).
  • Use principles to constrain reasoning (i.e. What are the important essentialist characteristics?, Which analogies are appropriate and which analogies are not in a given context?)
• NGSS focuses on
• Analogies and essentialist ideas are helpful in predicting and explaining, but the upper anchor students
  • can pick out which are appropriate and which are not appropriate for a particular context.
  • Can constrain their use