Tapping into student knowledge about science systems

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What do students know about science systems in the natural world? If students have a deep understanding of a science system, they should understand core principles and be able to use their knowledge to make inferences and carry out scientific investigations. Thus, the challenge of science assessment is to develop tasks that not only tap into declarative and procedural knowledge, but also schematic and strategic knowledge that allow students to demonstrate the ability to reason through complex systems and use existing knowledge to generate new understandings. By articulating a framework for structuring knowledge of science systems into the cross-cutting features of all complex systems: components and their roles, interactions among components, and emergent behaviors of a system, we can help students and teachers form a schema for understanding, inquiry, and transfer about science systems and also shape the design of assessments that measure these integrated knowledge structures.

The current study investigates the range of knowledge and skills addressed by existing middle school science assessments administered at state, national and international levels. We conducted an analysis of released and sample items related to ecosystems and chemistry from more than 30 exams.

In our analysis of existing items from 30 state, national, and international tests, we found that 98 static items and 6 dynamic items from 21 assessments met our search criteria of being related to either Ecosystems or Atoms and Molecules at the middle school level.

RESEARCH QUESTIONS

- Do existing test items tap into the science practices recommended by the NAEP national science framework?
- To what extent do existing items address the three model levels that characterize science systems: components and roles, interactions, and emergent behaviors?

METHODS

Sample. We identified 104 items related to Ecosystems and Atoms and Molecules at the middle school level from an analysis of 30 state, national, and international tests.

Coding categories. All items were coded independently by 2 researchers. Overall, the average pairwise percent agreement was 82.7% with a Cohen's Kappa of 0.67, indicating substantial agreement. All discrepancies in coding were discussed and reconciled among the reviewers.

SCIENCE PRACTICES

Identifying principles

- Describe, measure, or classify observations. State or recognize correct science principles.

Using principles

- Predict or explain observations of phenomena.

Using Inquiry

- Design experiments
- Conduct investigations
- Analyze data
- Draw conclusions

COGNITIVE DEMANDS

Declarative "Knowing that"

- Students can recall, define, represent, use and relate basic principles.

Procedural "Knowing how"

- Students can perform simple and complex procedures, e.g., controlling variables when designing experiments.

Schematic "Knowing why"

- Students can explain and predict natural phenomena.

Strategic "Knowing when and where to apply knowledge"

- Students can transfer knowledge and skills into new situations and reason through novel tasks to meet goals.

MODEL LEVELS

To tap into student knowledge of a science system, items should assess student knowledge across the model levels to ensure integration. Items were coded by the model level or levels the items assessed: Components, Interactions or Emergence.

	COMPONENTS	INTERACTIONS	EMERGENCE
ECOSYSTEMS	**Producers, consumers, decomposers.** All organisms need a source of energy and matter.	**Food webs.** As organisms interact with each other and their environment energy and matter flow through the system.	**Population dynamics.** Population levels over time emerge from interactions between organisms and their environment.
ATOMS AND MOLECULES	**Atoms and molecules.** Move in random motion, have intermolecular forces.	**Chemical interactions.** Particles interact to form structures. Environment influences the interactions that occur.	**Properties of matter.** Macroscopic features including the state and properties of matter emerge from the interactions of particles.

RESULTS

Science Practices. The large majority of items in the sample involve the first two science practices—identifying principles (56) and using principles (63). Very few items assess the other practices. Six items involve desiging investigations, five items involve analyzing data, and a single item asks students to conduct investigations. No items were coded to the science practice of drawing conclusions.

IDENTIFY PRINCIPLES	USE PRINCIPLES	DESIGN INVESTIGATIONS	CONDUCT INVESTIGATIONS	ANALYZE DATA	DRAW CONCLUSIONS
51	63	6	1	5	0

Cognitive Demands. The results of the item analyses show that only five items in the sample involve strategic thinking, while 94 items involve declarative knowledge. Reviewers also coded 52 items as involving "knowing why" (schematic knowledge) and 18 items involving "knowing how" (procedural knowledge).

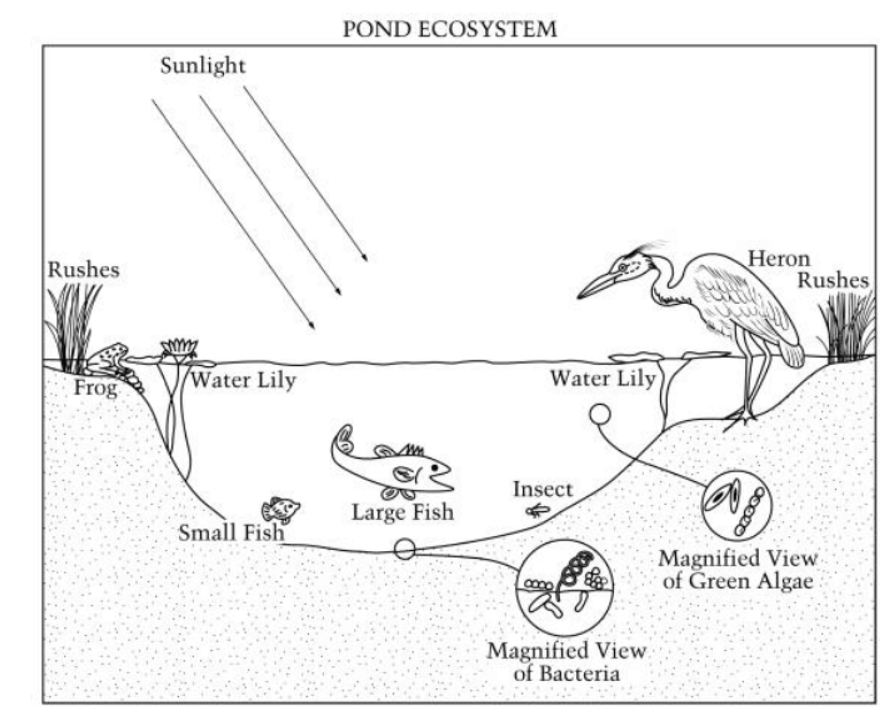
DECLARATIVE	PROCEDURAL	SCHEMATIC	STRATEGIC
89	16	52	5

Model Levels. In Ecosystems, reviewers found that most of the items assessed student knowledge of Interactions (30) or Roles (25). Reviewers only coded seven items to the Populations level. In Chemistry, 40 items were coded at the Emergent Properties level while fewer items assessed student knowledge of Components (7) and Interactions (9). The results suggest that student knowledge across the model levels of the science systems are not assessed evenly.

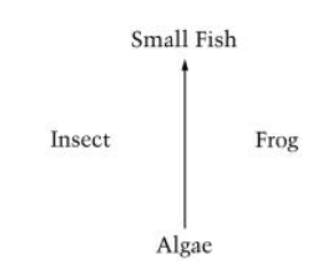
	COMPONENTS	INTERACTIONS	EMERGENCE
# OF ECOSYSTEMS ITEMS	23	29	7
# OF CHEMISTRY ITEMS	7	8	38

EXAMPLES OF EXISTING AND NEW ITEMS

Existing NAEP items



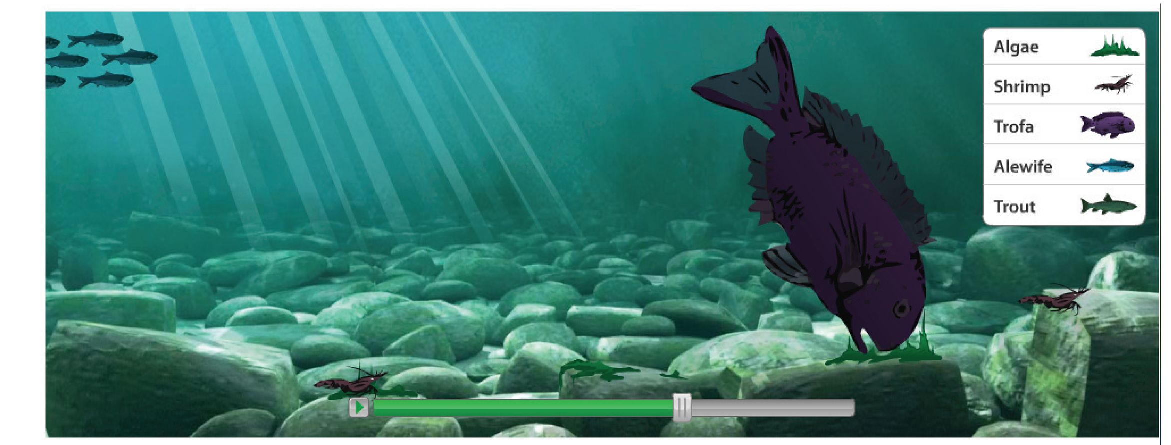
You will now finish a diagram of a food web in the pond. The food web shows what eats what in the pond system. Draw arrows in the diagram below from each living thing to the things that eat it. (The first arrow is drawn for you.)



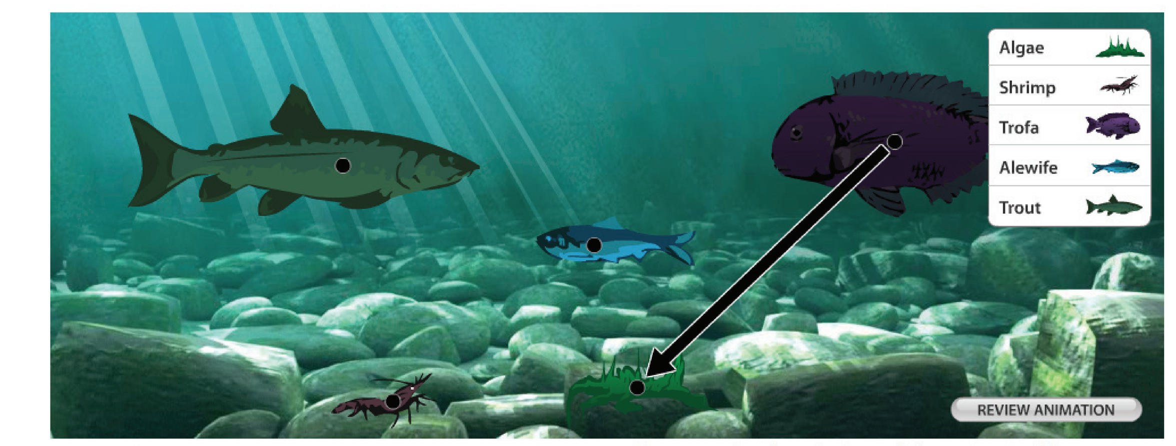
Pat has two kinds of plant food,"Quickgrow" and "Supergrow." What would be the best way for Pat to find out which plant food helps a particular type of houseplant grow the most?

A) Put some Quickgrow on a plant in the living room, put some Supergrow on a plant of the same type in the bedroom, and see which one grows the most.
B) Find out how much each kind of plant food costs, because the more expensive kind is probably better for growing plants.
C) Put some Quickgrow on a few plants, put the same amount of Supergrow on a few other plants of the same type, put all the plants in the same place, and see which group of plants grows the most.
D) Look at the advertisements for Quickgrow, look at the advertisements for Supergrow, and see which one says it helps plants grow the most.

New Items



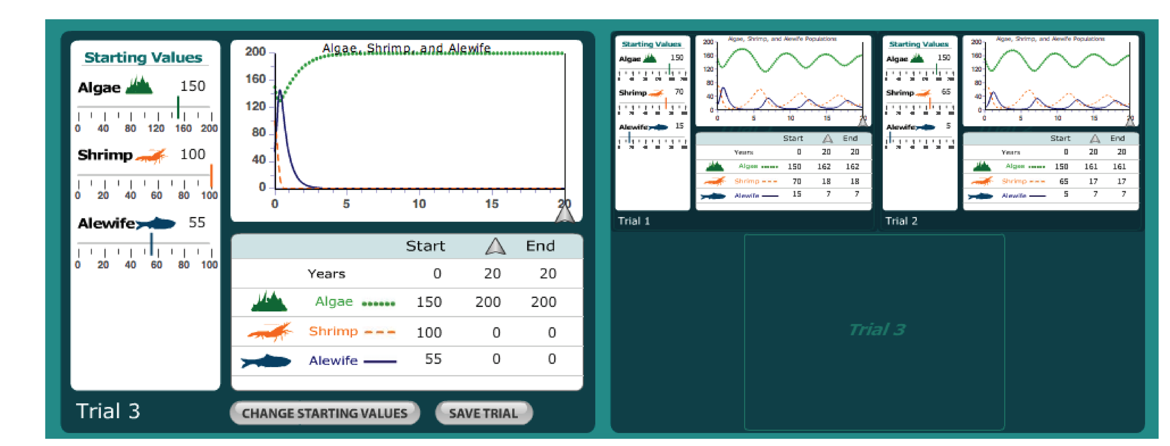
Observe the organisms interact in the mountain lake.



Make a food web diagram. Draw arrows to show the transfer of matter between organisms. Be sure to include each organism in the food web.

You can review the animation and then return to this diagram.

- **To draw an arrow, click and drag from one dot to another dot.**
- **To delete an arrow, double click on it.**



Set the sliders to find 3 different starting values that allow all organisms to survive for 20 years.

FINDINGS

1. Current assessments do not tap into a wide range of science skills, particularly science practices.
2. Few items tap strategic knowledge (e.g., require of knowledge transfer to new problems and complex reasoning skills).
3. Current items do not assess science systems evenly across the model levels.
4. New tasks are needed to tap into complex reasoning skills

NEXT STEPS

- Static items are limited in the range of skills they can assess directly. In ongoing work we are developing assessments using computer-based simulations that to provide interactive environments that allow students to demonstrate more complex inquiry and reasoning processes. We will compare student performance on static and interactive items.
- This fall, we will carry out cognitive labs to ensure the interactive items elicit the science practices they are designed to test.
- In the spring of 2011, we will carry out field tests to determine whether student responses to static and dynamic assessment items provide different information about students' proficiencies related to identifying principles, using principles and using inquiry.

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