Probing Middle School Students' Understanding of Ideas About Interdependence in Living Systems Through Content-Aligned Assessment

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Abstract

Project 2061 is developing an online collection of distractor-driven, multiple-choice assessment items aligned to middle school content standards in science, mathematics, and the nature of science from AAAS's *Benchmarks for Science Literacy* (AAAS, 1993) and the NRC's *National Science Education Standards* (NRC, 1996).

In this poster we report the results of pilot testing of items used to probe student thinking about middle school ideas regarding the dependence of organisms on other organisms for food. The items compare students' ability to answer questions involving direct versus indirect effects of changes to an ecosystem, and questions that use the names of organisms versus abstract symbols to represent those organisms.

Study I: Recognizing Direct vs. Recognizing Indirect Effects of Changes to Populations of Organisms in Food Webs

Introduction

Previous studies have indicated that high school students have a tendency to assume that changes in one population in a food web will not have any effect on another population that is not directly connected to it by a feeding relationship (Griffiths & Grant, 1985; Webb & Boltt, 1990). This was especially evident when populations of organisms were not within the same food chain on a food web diagram (Webb & Boltt, 1990).

In an effort to confirm these earlier results and further explore the implication this misconception has for assessment, students in grades 6-8 from nine middle schools throughout the country were given a set of assessment items aligned to the middle school idea: All organisms, both land-based and aquatic, are connected to other organisms by their need for food. This results in a global network of interconnections, which is referred to as a food web (benchmark 5D/M4*). We included items in which the connection between populations of organisms was direct (predator/prey); two, three, or more steps away; as well as items in which the populations in question were on different food chains within a food web diagram.

Conclusions

Through pilot testing of the items, we have learned that middle school students score much better on items that ask them to identify the consequences of changes to populations of organisms that are directly connected to each other in a feeding relationship (e.g., predator/prey) than when those connections are indirect (i.e., when the effect is mediated by one or more other organisms).

But the observation is difficult to interpret because the indirect effects items produced a much wider range of student success (from 25.0% correct to 76.7% correct) than the direct effects items (72.5% correct to 83.3% correct), suggesting that other factors besides the indirect vs. direct factor are operating. The items that we pilot tested differ in the number of organisms involved, how far removed the effect was from the originating cause, and whether or not the answer choices included an explanation for the effect. Although there is evidence that students have more difficulty with items that address indirect effects, the issue is complex and will require further research to better understand the nature of student thinking on items that ask them to recognize indirect effects in ecosystems.

Study II: Interpreting Food Web Diagrams That Use Names of Organisms vs. Abstract Symbols

Introduction

Leach et al. (1996) showed that more than 80% of 14-16-year-olds associated particular animals in a food web diagram with what they knew about them rather than with their position in a given food web diagram. In addition, Schollum (1983) showed that many 14-year-olds interpreted the arrows in a food web diagram or food chain as pointing from predator to prey. Therefore, when presented with an assessment item containing a diagram without the foothold of familiar populations of organisms, students may be unable to answer the question correctly, not because of a lack of understanding of the ideas being tested but because of a lack of familiarity with the conventions used in a food web diagram.

In an effort to confirm these earlier results in middle school students and to further explore the implication this misconception has for assessment, students in grades 6-8 from nine middle schools throughout the country were given sets of items in which two items were identical except for the substitution of symbols (i.e., A, B, and C) for the names of familiar organisms (i.e., worms, robins, and foxes) in the food web diagrams provided in the item. For each set, a randomly selected half of the students in each classroom received the version of the assessment item in which organisms were identified by symbols, and half of the students received the version in which the names of familiar organisms were provided.

Conclusions

Through pilot testing of the items, we have learned that a significant proportion of middle school students have difficulty answering questions involving food web diagrams when symbols are used to represent populations of organisms instead of the names of the organisms.The data suggest that students tend to use their knowledge of the feeding habits of particular organisms to answer food web diagram-based assessment items. In addition, when given a food web diagram in which the names of familiar organisms have been replaced by symbols, students tend to interpret the arrows within the diagrams as pointing from predator to prey, which is the reverse of what it should be, leading students to choose the answer that is the opposite of the correct answer.

The ultimate goal of instruction in science is the development of mental models that can be applied to a variety of real-world situations as well as a command of general statements describing those relationships. In assessment (as well as in instruction), a balance needs to be struck between presenting situations in which students can answer correctly simply based on their prior knowledge of the entities involved and situations that are too abstract for students to grasp. These findings have important implications for the design of assessment items in a variety of other contexts, including the life and physical sciences and mathematics. For example, we need to find out more about how students think about the symbols used in chemistry, as well as those used in algebra, and at what age such symbols begin to have meaning for students.

Study I: Recognizing Direct vs. Recognizing Indirect Effects of Changes to Populations of Organisms in Food Webs

Purpose of this Study:

To determine if middle school students recognize the interconnectedness of populations of organisms within a food web when those populations are two or more steps apart and/or on different chains within a food web diagram.

Overall Results:

Table 1. Percent correct for items addressing direct vs. indirect effects.

Item Context	% Correct	n	Item Context	% Correct	n
Recognizing Direct Effects	73.3%	75	Recognizing Indirect Effects	25.0%	136
	72.5%	182		40.0%	95
	83.3%	108		41.4%	99
	---	---		40.3%	159
	---	---		57.3%	103
	---	---		76.7%	116
Mean % Correct	76.4%		Mean % Correct	46.8%	
X^2	87.1		p value	<0.001	

Note: X^2 based on number of correct answers for pooled data in each category.

Sample Item: Recognizing Direct Effects

Populations of organisms are connected in a food web as described below.

If a disease kills most of the grasshoppers, which of the following describes what will happen to the grass and frogs? Use only the information in the diagram.

A. The amount of grass will increase, and the number of frogs will decrease.

B. The amount of grass will decrease, and the number of frogs will increase.

C. The amount of grass will increase, and the number of frogs will stay the same.

D. The amount of grass will stay the same, and the number of frogs will decrease.

Results:

	A	B	C	D	Not Sure	Total
n	55	6	5	6	3	75
%	73.3%	8.0%	6.7%	8.0%	4.0%	100%

Sample Written Comments:

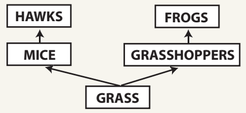
"Without predators grass will flourish. Without prey frogs will die." [Why A is correct]

"Because the frogs will eat the grass which will make it decrease." [Why B is correct]

"The grass could be eaten by something else." [Not sure]

Sample Item: Recognizing Indirect Effects

Populations of organisms are connected in a food web as described below.



Using only the information in the diagram, what will happen to the mice if a disease kills most of the frogs?

A. The number of mice will decrease because all of the organisms in this food web will decrease when the number of frogs decreases.

B. The number of mice will decrease because there will be more grasshoppers to eat the grass, so less grass will be available for the mice to eat.

C. The number of mice will stay the same because there would be no effect on organisms below frogs in the food web.

D. The number of mice will stay the same because frogs and mice are not connected in the food web.

Results:

	A	B	C	D	Not Sure	Total
n	9	41	10	34	5	99
%	9.1%	41.4%	10.1%	34.3%	5.1%	100%

Sample Written Comments:

"They are not connected so it won't effect the mice at all." [Why D is correct]

"Frogs and mice don't have any thing to do with each other." [Why D is correct]

Study II: Interpreting Food Web Diagrams That Use Names of Organisms vs. Abstract Symbols

Purpose of this Study:

To explore if middle school students are able to accurately interpret food web diagrams and answer assessment items when the names of familiar organisms are replaced with abstract symbols. If familiar organisms are replaced by symbols, will the students interpret the arrows in a food web diagram as pointing from prey to predator or predator to prey?

Overall Results:

Table 2. Percent correct for items that used names of organisms vs. symbols.

Item Context	% Correct	n	Item Context	% Correct	n
Items with Names of Organisms	73.3%	75	Items with Symbols for Organisms	34.9%	63
	41.4%	99		31.6%	98
	83.3%	108		19.1%	94
	57.3%	103		25.8%	97
	76.7%	116		31.1%	119
Mean % Correct	66.4%		Mean % Correct	28.5%	
X^2	143.6		p value	<0.001	

Note: X^2 based on number of correct answers for pooled data in each category.

Table 3. Percent of students who selected the wrong answer choice because they misinterpreted (reversed) the direction of arrows.

Item Context	% Reversed	n	Item Context	% Reversed	n
Items with Names of Organisms	8.0%	75	Items with Symbols for Organisms	39.7%	63
	---	---		---	---
	4.6%	108		56.4%	94
	7.8%	103		28.9%	97
	3.4%	116		41.2%	119
Mean % Reversed	6.0%		Mean % Reversed	41.6%	

Sample Item: Item with Organisms' Names

Populations of organisms are connected in a food web as described below.

Using only the information in the diagram, which of the following statements describes what will happen to the foxes if a disease kills most of the worms?

A. The number of foxes will decrease because there are more robins to eat the foxes.

B. The number of foxes will decrease because there will be fewer robins for the foxes to eat.

C. The number of foxes will not change because they are not connected to worms in the food web.

D. More information is needed to tell what will happen to the foxes.

Results:

	A	B	C	D	Not Sure	Total
n	4	89	3	15	5	116
%	3.5%	76.7%	2.6%	12.9%	4.3%	100%

Sample Written Comments:

Is there anything about this test question that was confusing? Explain.

"In the food web, the arrows should point to the left to show which animal they eat (i.e. worms←robin←foxes)."

"It doesn't show how the worms, robins and foxes are related. By putting 'eaten by' it is easier."

Sample Item: Item with Symbols

Populations of organisms A, B, and C are connected in a food web as described below.

Using only the information in the diagram, which of the following statements describes what will happen to population C if a disease kills most of the organisms in population A?

A. The number of organisms in population C will decrease because there will be fewer "A"s to eat the "B"s and so more "B"s to eat the "C"s.

B. The number of organisms in population C will decrease because if one population in a food chain decreases, all of the other populations also decrease.

C. The number of organisms in population C will decrease because there will be fewer "A"s for the "B"s to eat and so fewer "B"s will be available for the "C"s to eat.

D. The number of organisms in population C will not change because it is not connected to population A in the food web.

Results:

	A	B	C	D	Not Sure	Total
n	28	13	25	9	22	97
%	28.9%	13.4%	25.8%	9.2%	22.7%	100%

Sample Written Comments:

Is there anything about this test question that was confusing? Explain.

"Again, no such thing as an "A" Or "B" USE ANIMALS."

"The abc thing could be animals."

"The question doesn't make sense."

"Who's eating who?"

References: American Association for the Advancement of Science. (1993). *Benchmarks for science literacy*. New York: Oxford University Press. ■ American Association for the Advancement of Science. (2007). *Atlas of science literacy*. Volume 2. Washington D.C.: Author. ■ National Research Council. (1996). *National science education standards*. Washington, DC: National Academy Press. ■ Griffiths, A. K., & Grant, B. A. C. (1985). High schools students' understanding of food webs: Identification of a learning hierarchy and related misconceptions. *Journal of Research in Science Teaching, 22*(5), 421-436. ■ Leach, J., Driver, R., Scott, P., & Wood-Robinson, C. (1996). Children's ideas about ecology 3: Ideas found in children aged 5-16 about the interdependency of organisms. *International Journal of Science Education, 18*(2), 129-141. ■ Schollum, B. (1983). Arrows in science diagrams: Help or hindrance for pupils? *Research in Science Education, 13*, 45-59. ■ Webb, P., & Boltt, G. (1990). Food chain to food web: A natural progression? *Journal of Biological Education 24*(3), 187-190.

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