Assessing Students' Understanding of Controlling Variables

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As part of our work on developing distractor-driven multiple-choice assessment items, we designed items that target the following benchmark:

If more than one variable changes at the same time in an experiment, the outcome of the experiment may not be clearly attributable to any one of the variables. (*Benchmarks for Science Literacy*, AAAS, 1993, p. 12).

The two studies reported here focus on pilot test data from items that ask students to choose an idea that could be tested by using a particular controlled experimental setup.

Procedure: The studies were performed in a suburban public school in the northeastern United States, where 10% of the students were eligible for free and reduced lunch. Students were heterogeneously placed in classrooms.

During pilot-testing, students responded in writing to questions about each item. For example:

1. Is there anything about this test question that was confusing? Explain.
2. Circle any words on the test question you don't understand or aren't familiar with.
3. *For each answer choice*: Is answer choice correct? Explain why. Yes No Not Sure
4. Did you guess when you answered the test question? Yes No
5. Was the picture helpful? Yes No

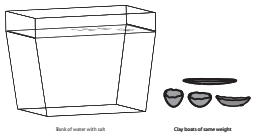
Conclusions

- When ideas about controlling variables (CV) are developing, a single assessment question is unlikely to provide a stable measure of student understanding. In Study 1, 56.1% of the students either got all three questions right or all three questions wrong, but 43.9% of the students got some right and some wrong. This partial understanding was detected only by examining students' responses across all three items, something that would have been overlooked if only one of the items was used.
- When students correctly answer a series of questions about controlling variables, they may still invoke ideas they have about the situation. In Study 1, students who used ideas they had about the situation rather than using ideas about CV did so unsystematically and often in combination with ideas about CV.
- Adding a follow-up question asking students "why" they selected an answer choice may be a good way to identify students who used knowledge of context when written comments are not available. In Study 2, 60% of the students who selected the correct answer based on what they knew about the context were detected by using a follow-up question.

Study 1: How consistent are students in their responses to three items that are highly similar in structure but differ in the nature of the context involved? To what extent do students draw on their knowledge of the context? Sixty six (66) eighth grade students responded to all 3 items below:

Item 1

A group of students uses clay to make boats of the same weight but different shapes. The students add 4 tablespoons of salt in a water tank and mix the water.



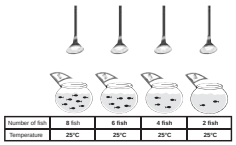
They place the boats in the tank and see if the boats float or if they sink.

What are the students testing with this experiment?

A. If shape affects the floating of the boats.
B. If weight affects the floating of the boats.
C. If shape and weight affect the floating of the boats.
D. If shape, weight, and the amount of salt in the water affect the floating of the boats.

Item 2

A student is interested in the behavior of fish. He has 4 fish bowls and 20 goldfish. He puts 8 fish in the first bowl, 6 fish in the second bowl, 4 fish in the third bowl and 2 fish in the fourth bowl. He places each fish bowl under light, he keeps the temperature at 25°C for all four bowls, and he observes the behavior of the fish.



Number of fish	8 fish	6 fish	4 fish	2 fish
Temperature	25°C	25°C	25°C	25°C

What is the student testing?

A. If the number of fish in the fish bowl affects the behavior of the fish.
B. If the temperature of the fish bowl affects the behavior of the fish.
C. If the temperature and the amount of light affect the behavior of the fish.
D. If the number of fish, the temperature, and the amount of light affect the behavior of the fish.

Item 3

A sailing team wants to select one out of three fabrics for their new uniform. They decide to do the following experiment:

They cut the same size pieces from each fabric and wet each piece with the same amount of water.

They hang the pieces in the sunlight and they check every 10 min to see if any of them is dry.

What is the team testing with this experiment?

A. If the amount of water affects how fast each fabric dries.
B. If the material of each fabric affects how fast the fabric dries.
C. If the material of each fabric and the amount of water affect how fast the fabric dries.
D. If the material of each fabric, the amount of water, and the amount of light affect how fast the fabric dries.

Results for Study 1

Percent correct for EACH item: 65.2%, 65.2%, and 69.7%, respectively.

Table 1. Students with correct answers across ALL items and students who used knowledge of context.

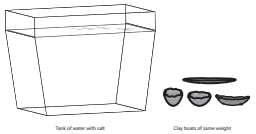
# Items Correct	# of Students	% of Students	# Who Used Context Knowledge (revealed in written comments)	% Who Used Context Knowledge
3	30	45.5%	4	13.3% (4/30)
2	13	19.7%	2	15.4% (2/13)
1	16	24.2%	3	18.8% (3/16)
0	7	10.6%	3	42.9% (3/7)
Total	**66**	**100.0%**	**12**	**18.2% (12/66)**

Regardless of how many items students answered correctly, some students used knowledge of context in answering.

Study 2: Can the addition of a follow-up question be used to identify students' use of context knowledge? Two hundred fourteen (214) seventh grade students responded to one item alone or one item with a follow-up question:

Item 1

A group of students uses clay to make boats of different shapes. All the boats they make have the same weight. The students add 4 tablespoons of salt in the water tank and mix the water. They place the boats in the tank and see if the boats float or if they sink.



What can the students find out from doing just this experiment?

A. If shape affects the floating of the boats.
B. If weight affects the floating of the boats.
C. If weight and amount of salt affect the floating of the boats.
D. If shape, weight, and the amount of salt in the water affect the floating of the boats.

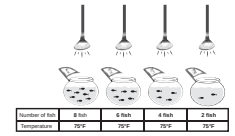
Second Level Item to Accompany Item 1

Why did you choose that answer?

E. Because I already know what affects the floating of the boats.
F. Because that is what is allowed to change in this experiment.
G. Because that is what stays the same in this experiment.
H. Because that is what the student decided to include in this experiment.

Item 2

A student is interested in the behavior of fish. He has 4 fish bowls and 20 goldfish. He puts 8 fish in the first bowl, 6 fish in the second bowl, 4 fish in the third bowl and 2 fish in the fourth bowl. He places each fish bowl under light, he keeps the temperature at 75°F for all four bowls, and he observes the behavior of the fish.



Number of fish	8 fish	6 fish	4 fish	2 fish
Temperature	75°F	75°F	75°F	75°F

What can the student find out from doing just this experiment?

A. If the number of fish in the fish bowl affects the behavior of the fish.
B. If the temperature of the fish bowl affects the behavior of the fish.
C. If the temperature and the amount of light affect the behavior of the fish.
D. If the number of fish, the temperature, and the amount of light affect the behavior of the fish.

Second Level Item to Accompany Item 2

Why did you choose that answer?

E. Because I already know what affects the behavior of fish.
F. Because that is what is allowed to change in this experiment.
G. Because that is what stays the same in this experiment.
H. Because that is what the student decided to include in this experiment.

Item 3

A swimming team wants to select one of three fabrics for their new swimsuits. Each fabric is made of a different material. The team decides to do the following experiment:

They cut the same size pieces from each fabric and wet each piece with the same amount of water. They hang the pieces in the sunlight and they check every 2 minutes to see if any of the pieces are dry.

What can the team find out about the different fabrics from doing just this experiment?

A. If the amount of water affects how long it takes them to dry.
B. If the type of fabric affects how long it takes them to dry.
C. If the amount of water and the amount of light affect how long it takes them to dry.
D. If the type of fabric, the amount of water, and the amount of light affect how long it takes them to dry.

Second Level Item to Accompany Item 3

Why did you choose that answer?

E. Because I already know what affects how long it takes them to dry.
F. Because that is what is allowed to change in this experiment.
G. Because that is what stays the same in this experiment.
H. Because that is what the student decided to include in this experiment.

Results for Study 2

Table 2. Students with correct answer for item alone and item paired with follow-up question.

Item	Item alone correct	Item correct when paired with follow-up item
1	18/37 (48.7%)	23/37 (62.6%)
2	13/34 (38.2%)	13/34 (38.2%)
3	13/36 (36.1%)	19/36 (52.8%)
Total	**44/107 (41.1%)**	**55/107 (51.4%)**

Table 3. Students whose comments indicated that they used context knowledge (not CV) to answer the question.

Items	# of students	% of students
Items alone	23 / 96	24%
Items paired w/ follow-up item	15 / 100	15%

Nine of these 15 students (60%) chose answer choice E, that is, they based their answer on knowledge of the context.

A follow-up question is a good way to identify students who based their answers on context knowledge rather than knowledge of CV.

For more information: AAAS Project 2061 http://www.project2061.org. The research reported here was supported by the National Science Foundation (0352473).