READY...SET...GO!

Fourth-grade students learn to identify testable questions by competing to "outfit a scientist" in a classroom relay race.

By Erin E. Morgan and Laurel S. Hiebert

Posing an appropriate question is the first step in designing an investigation to better understand one's surroundings, gain knowledge, or solve a problem. When asked to write an investigative question for an open inquiry lesson with hermit crabs, one of our fourth-grade students gave the unexpected response, "Will a hermit crab go nuts in a cup of colored water with a jelly bean?" Rather than being an exception, problematic questions like this one were posed by our entire class. Effective inquiry-based learning motivates students to ask questions and design scientific investigations related to their own interests and observations. However, students may struggle with open inquiry if they do not have experience recognizing and designing testable questions. To address this, we created an activity called the "Testable Question Relay" as part of a fourth-grade unit on conducting science experiments. In the relay, student teams raced to "outfit a scientist" by correctly categorizing questions as testable or untestable and earning scientific tools. This activity assists upper-elementary students in recognizing the components of good investigative questions, addresses associated misconceptions, and aids students in developing questions appropriate for scientific investigation.

Activity Overview

In the Testable Question Relay, teams of student "fieldworkers" are asked to categorize a set of written questions as scientifically "testable" or "untestable." The object of the race is for each team to "outfit a scientist" by placing all cards in the correct category. Correct placement is rewarded with pieces of scientific gear, such as clothing or tools. We used a shovel, bucket, transect tape, and boots—representing a field ecologist—as prizes (Figure 1). A common measuring tape could also be used in place of a transect tape. Teams outfit their scientist and win the race by earning all the reward items and having one teammate wear or hold all the items. We taught this lesson within the larger context of a marine science class, and so chose to have students outfit a marine field ecologist; however, teachers may substitute different tools to represent different types of scientists depending on their own curricula. Suggestions are provided in Figure 1.

Figure 1.

Game materials.

- Game questions (1 pack of 16 questions per team)
- Masking tape
- Marker
- Space (approx. 30' x 30')
- 3 quadrats (0.5 m x 0.5 m)—optional (areas may also be delineated with masking tape)
- Prizes for student "scientists"
- Tools of the field ecologist used as prizes for student "scientists," including bucket, shovel, quadrat, transect tape, and rubber boots. Quadrats, square grids made out of plastic pipe, designate study areas, whereas transect tapes are used to mark a line along a study site.

Suggestions for scientific tools that may be used as costumes for student "scientists:"

Field Ecologist	Scientific Diver	Ornithologist
Shovels	Mask	Binoculars
Boots	Snorkel	Field Guide
Buckets	Field Notebook	Map
Transect Tape	Fins	Compass

Lesson Preparation

To prepare for this lesson, create a large, open area (approximately 30' × 30') in the classroom, gym, or playground. The chosen area should be free from obstructions such as desks, chairs, or glass doors that could pose a safety hazard to students racing across the open space. Using masking tape, mark a starting line on the floor on one end of the room and organize three "study sites" across from the starting line at the opposite end of the room. Each study site should contain a plastic 0.5 m "quadrat," which is a grid used by field ecologists to delineate a particular area of study. Quadrats are usually open squares made of PVC pipe, divided into smaller squares of equal areas with string. Spread out a set of 16 laminated questions face down on the floor inside each quadrat (Figure 2, p. 42). If quadrats are not available, simply spread the cards out on the floor, or delineate a study site with masking tape boundaries. Next to each quadrat, use masking tape to label spaces for "Testable" and "Untestable" questions. Classroom preparation takes approximately 20 minutes. See Figure 3 (p. 43) for a diagram of the classroom setup.

Preassessment

Begin the lesson by engaging the students in a brief discussion of untestable questions (approximately 10–15 minutes). Live animals or plants may provide an excellent focal point for question examples. We brought hermit crabs into the classroom as part of our marine science curriculum. However, other small class pets (such as goldfish) or classroom plants could also be used. Place the animal or plant in the front of the room where students can observe its behavior. Explain that you have some questions about the animal, but don't think you can test them with a science experiment. Questions might include:

- "Does our hermit crab like television?
- "Will pea plants placed in sunlight always grow taller than pea plants placed in the shade?"
- "Will our hermit crab react to a jelly bean?"

Encourage students to consider why each question cannot be tested with an experiment, given that testable questions involve variables that can be measured or observed. Discuss ways to change the three examples into testable questions, such as "What is the average speed that a fish swims in 10 minutes?" Before beginning the relay, students should recognize that (1) words that indicate emotions, such as "like," can only be used appropriately with organisms that can actually express emotion; (2) nonspecific language, such as "react," must be defined in order to be measureable; and (3) investigations answer questions within a definitive time period. See Figure 4 (p. 44) for other examples of questions that address each of these three themes: (1) immeasurable variables; (2) nonspecific time frames; and (3) nonspecific terminology.

We found that students had the least trouble understanding the theme of "immeasurable variables." Several students quickly pointed out that you cannot ask a hermit crab whether it likes television. Changing these questions generally involved the students authoring a completely different, testable question about the organism named in the original statement.

Students did not initially identify words such as "always," "never," or "usually" as problematic. However, once we emphasized these words and pressed the students as to whether they would "live forever" in order to know if something *always* happened, they quickly perceived the second theme—that an experiment had to occur over a reasonable time frame. Altering these sentences generally required students to simply look at a question, find "time" words that were nonspecific, and replace those words with a specific time frame. For example, the question "Will pea plants placed in sunlight always grow taller than pea plants placed in shade?" might be altered to ask, "Over two weeks, will pea plants placed in sunlight grow taller than those placed in shade?"

We found that students had the most difficulty with the third theme: identifying questions with nonspecific terminology as being untestable. Questions such as, "Will a hermit crab react to a piece of food?" sound deceptively scientific; most students began the lesson by asserting that this could certainly be tested and observed. To address this misconception, we found that it was useful to provide the students with several pairs of example questions in our initial discussion; one question with nonspecific terminology, and the other rewritten with specific terminology. For example, the question "Will plants respond to fertilizer?" can be paired with "Will fertilized plants grow taller than unfertilized plants in one month?" Once presented with such an example, students were able to pick out the more specific question in the pair. We then circled the nonspecific word "respond" and had students describe how this was modified in the second sentence (i.e., "grow taller than"). Teachers can challenge their students with subsequent examples, and require students to identify and circle nonspecific words and verbally alter untestable questions. Emphasizing that scientists must often use a tool (e.g., rulers, scales, stopwatches) to measure an experiment's outcome and that the experiment must have a definitive time period can help students think of ways to rewrite nonspecific questions into questions that could be tested.

The Relay

Once students have been introduced to the key lesson concept, divide the class into teams and have students line up behind the starting tape. Designate one student on each team as the "scientist" and the rest of the students as "fieldworkers." Explain the following race rules:

(1) Students must begin behind the start line.
(2) When the instructor says "start!" the first student in line must crab-walk from the line to the "study site" on the opposite side of the room.
(3) The student should choose one of the facedown cards from the quadrat. They must read the question to themselves and determine whether it is testable.
(4) The student should place the card into the category they believe is correct.
(5) The student should then walk (normally) back to join their teammates and return to the end of the line. The next student in line then repeats these steps.

Assign an adult judge to each study site to monitor team progress using a key to the correct categorization of the questions. Once students place 8 of the 16 cards into categories, the judge should briefly pause the team's activity to assess the cards. If all eight cards are placed correctly, the judge should call the team's scientist to the study site to receive two pieces of scientific gear as prizes. After the scientist returns to his or her team, the race continues and students attempt to correctly place the remaining eight cards.

If some of the cards are in the incorrect category, the adult judge should shuffle those cards and give them to the team's scientist, who then must return to his or her team before resuming the game. At that point, team members work together to determine the correct category for the remaining cards.

The team should then discuss the cards as a group. Individuals continue to race, bringing the "incorrect" cards back to the study site to make a second attempt at a correct placement. This process engages students in peer learning and helps individuals grasp which cards they missed and why, while the game is still in progress.

Figure 2.
"Study site" quadrat.

Figure 3.
Classroom setup for the testable question relay.

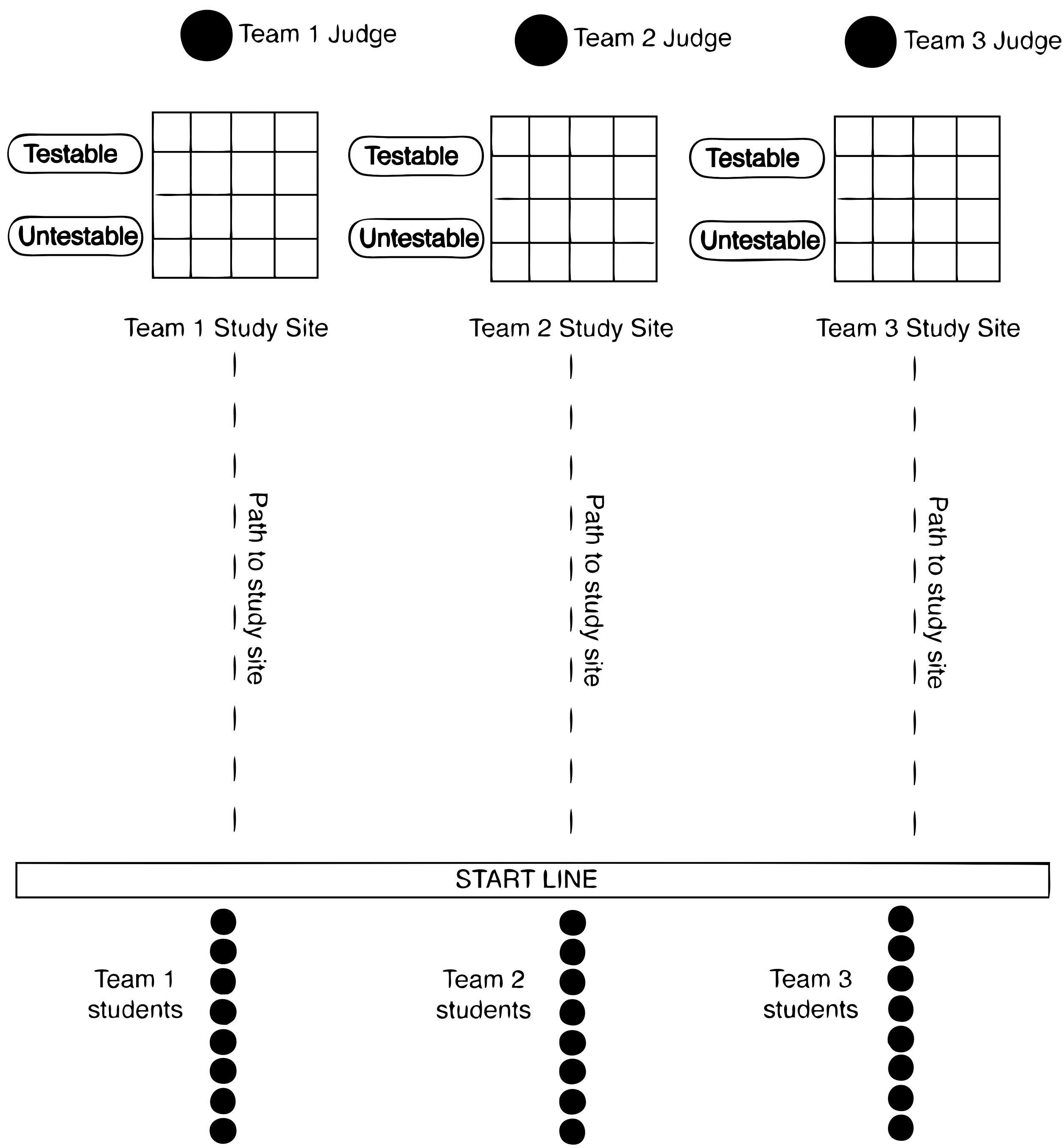

Figure 4.

Example questions, organized by themes.

Theme 1 Immeasurable variables	Theme 2 Nonspecific time frames	Theme 3 Nonspecific terminology
Untestable: Does a fish get angry if you take away its food? Will a frog be lonely if it is kept in a tank by itself? Do red and green algae smell different to a shore crab?	*Untestable*: Will hermit crabs always use empty shells for protection? Does a turtle usually hide in its shell in the afternoon? Do birds often return to the same tree to nest?	*Untestable*: Will "sea monkeys" (brine shrimp) react to freshwater? Will a plant respond to additions of fertilizer? Are fish eggs affected by temperature?
Testable: Will purple sea urchins eat the green alga "sea lettuce"? Do ants follow specific paths from their burrows to a food source? Will seeds from salt marsh plants sprout in freshwater?	*Testable*: Does kelp grow faster during the day or night? Does a turtle spend an equal amount of time hiding and foraging over 12 hours? Will a hummingbird nest in the same bush each spring over a five-year period?	*Testable*: Will "sea monkeys" (brine shrimp) survive in freshwater for one week? Will plants potted in fertilized soil grow taller than plants potted in unfertilized soil, over the course of one month? Will salmon eggs hatch in water that is 70°F?

Once the first half of the cards have been placed correctly, the team scientist may obtain the prizes from the adult judge. Students then continue to race, picking the second half of the cards from the quadrat. Once a team correctly places all 16 cards, the team scientist receives the last two pieces of scientific gear from the adult judge. He or she then puts on or holds all of the equipment. The first team to outfit their scientist wins the race!

Inclusive Learning

Disabilities or learning challenges may make portions of the testable question relay prohibitive for some students. We suggest the following modifications for students with varying needs.

Mobility: The relay does not need to include a "distance" between the start and finish lines. Rather, teams could sit around tables with the question cards and categories in the center. Teams could indicate their completion of a round by ringing a bell or raising their hands. Teachers may consider presenting this lesson as a testable question game show, instead of a relay, and have teams take turns choosing and categorizing questions. Teams could then earn points and prizes in turn for correct question placements. Bonus points could be awarded for correct explanations for a given categorization. Teams could also "steal" points by offering correct explanations if the turn-taking team could not provide an answer. In this way, students would learn from the explanations provided by their peers.

Language proficiency: Adult judges may assist students with reading and interpreting questions. Students could pick a question and the adult judge could read the question aloud. The instructor might require the students to orally explain their reasoning, providing a simple assessment of comprehension during the game. If a teacher chooses to conduct the lesson as a game show, then he or she could read each question aloud.

Concluding the Lesson

Once a team wins the Testable Question Relay, have all of the students sit on the floor. Review several of the game questions, challenging the students to explain why a question was testable or not and to offer suggestions for rewriting untestable questions. Small-group discussions with each team, led by the adult judges, can also benefit students by providing more focused explanations of questions that were particularly challenging for that team. Have students return to their seats and conclude the lesson by asking students to identify words that made certain game questions untestable.

Figure 5.

Suggested postlesson student assessment.

Materials	Questions
Measuring tape A plant Water Salt	Will a plant grow taller in freshwater or salt water over two weeks? In two weeks, will plants grow taller if watered once a day or twice a day? Do plants hate salt water? Do plants react to measuring tapes? Will plants grow forever?

Subsequent Assessment

In a subsequent review game, our students demonstrated an ability to select testable questions from a list, explain why other questions were not testable, and offer suggestions for modification. This indicates that the testable question relay is effective at aiding students in recognizing characteristics of testable questions. Instructors may also assess student comprehension by presenting students with a number of materials and a list of questions (Figure 5). From this information, students should be able to identify which questions are testable using the given materials and to explain their reasoning.

A Precursor to Inquiry

Students must know how to ask appropriate questions in order to use a scientific method to systematically explore their surroundings. Flannagan (2008) noted that it takes practice and guidance for students to become proficient at designing investigative questions and suggests teaching students a four-question strategy (modified from Cothron, Giese, and Rezba 1989) as a conceptual framework for designing appropriate experimental questions. This strategy involves encouraging students to observe how an object acts (e.g., hermit crabs crawl), to recognize any materials available or needed to affect the observed action, and to determine how to measure or describe the object's response.

Flannagan's strategy provides students with a tool to aid in question writing; however, it is beneficial for students to recognize components of investigative questions before attempting to author their own. We have found that the testable question relay is a good precursor to lessons on developing questioning strategies and to open inquiry lessons. This activity best follows a structured inquiry lesson, as it acts as an introduction to discerning differences between testable and untestable questions. Not only do students find the testable question relay exciting and engaging, they also leave the classroom better prepared to design scientific investigations that explore their surroundings, facilitate learning, and solve real-world problems. ■

Erin E. Morgan (emorgan300@comcast.net) *and Laurel S. Hiebert were K–12 fellows and graduate students at the Oregon Institute of Marine Biology (OIMB) in Charleston, Oregon. Laurel is currently pursuing her PhD at OIMB.*

Acknowledgments

The authors would like to thank Patricia Mace, Dr. Alan Shanks, and Dr. Janet Hodder for organizing the GK–12 program at OIMB, and for their encouragement and support in the creation of this manuscript. This manuscript was produced with funding from National Science Foundation Grant No. 0638731.

References

Cothron, J.H., R.N. Giese, and R.J. Rezba. 1989. *Students and research: Practical strategies for science classrooms and competitions.* Dubuque, IA: Kendall/Hunt.

Flannagan, J.S. 2008. Caution! Scientists in the making. *Science Scope* 32 (1): 61–63.

Connecting to the Standards

This article relates to the following *National Science Education Standards* (NRC 1996):

Content Standards

Grades K–4

Standard A: Science as Inquiry

- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry

National Research Council (NRC). 1996. *National science education standards.* Washington, DC: National Academies Press.