ABA 7608

Singapore 1999

ASSESSING CRITICAL THINKING

Instructor: Dr. Alec Fisher

Mon, Tue, Thur, Fri

This course will review alternative conceptions of critical thinking in order to develop a clear articulation of the competencies critical thinkers display (e.g, the ability to clarify concepts, to judge the reliability of sources of information, to make rational decisions). Against this backdrop we shall study some good models for assessing critical thinking abilities and some of the strengths and weaknesses of classical attempts to assess critical thinking will be reviewed (e..g the Watson-Glaser Test, the Cornell Tests, the Ennis-Weir Essay Test). New assessment tools will be introduced and elaborated, including open ended assessment items and multiple rating items, and the development of scoring rubrics for these items will be illustrated. Problems about the validity and reliability of assessments of critical thinking will be discussed, and some possible solutions to these problems developed. Participants will be given an opportunity to use these models to develop their own assessment items and scoring rubrics.

Monday

(I) What is Critical Thinking and What are its Constituent Competencies? Different conceptions of critical thinking, from Dewey, Glaser, Ennis, Scriven and others suggest different underlying competencies (though with many in common). We begin by getting clear what thinking skills we want to teach and assess, looking especially at examples of good and bad thinking.

Background Reading: Fisher and Scriven *Critical Thinking; Its Definition and Assessment* (1997) . Selections from Chapters 1-3.

Assignment: Answer the Ennis Weir Essay Test

Tuesday

(II) Writing Good Prompts for Assessing Critical Thinking; also Some Classic Tests Reviewed.

We look at some good examples of writing prompts. Also some classic attempts to assess critical thinking are reviewed to see what we can learn from them. All examples are chosen because both their strengths and weaknesses are illuminating; it is also fun to see how well you can do them!

Background Reading: Robert Swartz *'Developing Writing Prompts for Assessing Thinking and Content Learning in Science Classrooms'* (photocopies will be supplied); Fisher and Scriven (1997) Ch.4.

Assignment: For a topic **you** teach, devise two prompts which will test critical thinking and write a good answer to one of them

Thursday

(III) Multiple Rating Questions: How to Write and Score Them.
There are problems both with multiple choice and with essay assessments of thinking processes. We explain an alternative way of writing critical thinking questions and assessing the answers which seems to overcome many of the difficulties.

Background Reading: Fisher and Scriven (1997) Ch.6.

Assignment: Devise one multiple rating question which is relevant to your teaching, for circulation to colleagues in the class tomorrow (write a separate scoring key).

Friday

(IV) Validity and Reliability; Problems and Solutions.
How can you be sure that your critical thinking test is assessing critical thinking and not something else (like shared beliefs)? What can be done when two teachers disagree about the critical thinking ability displayed in a given performance? How do we decide who is right? We answer these questions with the help of some previous examples and by reference to examples produced by members of the class.

Background Reading: Fisher and Scriven (1997) Ch.7.

Assignment: (for those who wish to gain credit for the course). Write an assignment which aims to assess one critical thinking competency which is important in a course you teach. Give a scoring key and justify it (not more than 2,000 words).

Note on Reading: The text for the course is the book by Alec Fisher and Michael Scriven *Critical Thinking: Its Definition and Assessment*, published by the Centre for Research in Critical Thinking, UEA, Norwich, UK and Edgepress, CA, USA. Another excellent book which may be relevant to your interests is Evaluating Critical Thinking by Stephen Norris and Robert Ennis, published by Critical Thinking Press, 1989.

THE ENNIS-WEIR CRITICAL THINKING ESSAY TEST

TEST • MANUAL • CRITERIA • SCORING SHEET
AN INSTRUMENT FOR TEACHING AND TESTING

by

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THE ENNIS-WEIR CRITICAL THINKING ESSAY TEST AN INSTRUMENT FOR TESTING AND TEACHING

DIRECTIONS

Read the letter to the editor of the Moorburg newspaper. Consider it paragraph by paragraph and as a total argument. Then write a letter to the editor in response to this one. For each paragraph in the letter you are about to read, write a paragraph in reply telling whether you believe the thinking good or bad. Also write a closing paragraph about the total argument. *Defend your judgments with reasons.*

Your answer should have nine numbered paragraphs. Numbers one through eight should give your reactions to paragraphs one through eight in the letter. Your paragraph number nine should give your overall evaluation of the letter considered as one total argument. Each paragraph, including the last, should contain your reason(s).

Spend about 10 minutes reading the letter and thinking about it. Then write for not more than 30 minutes (about three minutes for each of your short paragraphs). The maximum total time for the test is 40 minutes.

Do not forget to give your reasons in each paragraph. Please write clearly.

Sign your name to your letter. You are a local citizen, and this topic concerns you.

Remember, write *nine numbered paragraphs* and give reasons.

THE MOORBURG LETTER

230 Sycamore Street
Moorburg
April 10

Dear Editor:

Overnight parking on all streets in Moorburg should be eliminated. To achieve this goal, parking should be prohibited from 2 a.m. to 6 a.m. There are a number of reasons why any intelligent citizen should agree.

1. For one thing, to park overnight is to have a garage in the streets. Now it is illegal for anyone to have a garage in the city streets. Clearly, then, it should be against the law to park overnight in the streets.

2. Three important streets, Lincoln Avenue, Marquand Avenue, and West Main Street, are very narrow. With cars parked on the streets, there really isn't room for the heavy traffic that passes over them in the afternoon rush hour. When driving home in the afternoon after work, it takes me thirty-five minutes to make a trip that takes ten minutes during the uncrowded time. If there were no cars parked on the side of these streets, they could handle considerably more traffic.

3. Traffic on some streets is also bad in the morning when factory workers are on their way to the 6 a.m. shift. If there were no cars parked on these streets between 2 a.m. and 6 a.m., then there would be more room for this traffic.

4. Furthermore, there can be no doubt that, in general, overnight parking on the streets is undesirable. It is definitely bad and should be opposed.

5. If parking is prohibited from 2 a.m. to 6 a.m., then accidents between parked and moving vehicles will be nearly eliminated during this period. All intelligent citizens would regard the near elimination of accidents in any period as highly desirable. So, we should be in favor of prohibiting parking from 2 a.m. to 6 a.m.

6. Last month, the Chief of Police, Burgess Jones, ran an experiment which proves that parking should be prohibited from 2 a.m. to 6 a.m. On one of our busiest streets, Marquand Avenue, he placed experimental signs for one day. The signs prohibited parking from 2 a.m. to 6 a.m. During the four-hour period, there was **not one accident** on Marquand. Everyone knows, of course, that there have been over four hundred accidents on Marquand during the past year.

7. The opponents of my suggestions have said that conditions are safe enough now. These people don't know what "safe" really means. **Conditions are not safe if there's even the slightest possible chance for an accident.** That's what "safe" means. So, conditions are not safe the way they are now.

8. Finally, let me point out that the Director of the National Traffic Safety Council, Kenneth O. Taylor, has strongly recommended that overnight street parking be prevented on busy streets in cities the size of Moorburg. The National Association of Police Chiefs has made the same recommendation. Both suggest that prohibiting parking from 2 a.m. to 6 a.m. is the best way to prevent overnight parking.

I invite those who disagree, as well as those who agree with me, to react to my letter through the editor of this paper. Let's get this issue out in the open.

Sincerely,

Robert R. Raywift

8 Developing Writing Prompts for Assessing Thinking and Content Learning in Science Classrooms

ROBERT SWARTZ

Science education is changing. We still see many classrooms where students passively learn information about the natural world from written texts. However, we also see a growing emphasis on helping students achieve a deeper connection to the natural world through active and constructive learning. With this approach, students are the center of the science classroom. Teachers and texts facilitate the process of active learning instead of merely providing students with its inert products. Figure 8.1 outlines how these two types of science classrooms differ.

To be sure, scientific principles and information about the natural world must play a role in the new science classroom. But rather than give such information to students as the focus of their learning, it should be available to students who will seek it as they actively construct new understandings. In the new science classroom, emphasis is placed on the development of:

- processes through which students can construct meaning,
- processes students can use to validate their understandings, and
- strategies through which students can use their insights in constructive problem solving.

Basic concepts of science together with scientific principles that flesh out these concepts are valuable in the new science classroom only insofar as they are appropriately embedded in these processes.

As instructional goals change, so too must assessment of whether we are achieving these goals. We must not only change what we assess but how we assess it. Relying primarily on standard ways of assess-

Note: This article is an adaptation of Chapter 1 of a longer monograph by Robert Swartz in *New Ways to Assess Learning in Science*, edited by S. Loucks-Horsley (Miami, Fla.: Miami Museum of Science, 1991).

FIGURE 8.1

Traditional Science Class vs. New Science Class

TRADITIONAL CLASS	NEW CLASS
• Students are told what others think the natural work is like.	• Students are guided to developed their own conception of the world.
• Students are told how science works.	• Students test and modify their constructs through scientific thinking.
• Students are told about contemporary issues in science.	• Students make use of their understanding in science to think through issues.
• Teachers and texts give students information to learn.	• Teachers and texts facilitate understanding and are resources for information students use in problem solving.

ing whether students retain basic information is no longer appropriate. Modes of assessment that reveal and enhance the use of the processes listed above must replace more traditional modes of assessment.

This means that the primary emphasis in assessment must be on student performances that demonstrate the use of these active processes. This chapter explains how teachers can prompt extended written (or oral) responses by students in ways that bring out their active thinking and learning so that its quality can be assessed. In emphasizing the design of assessment prompts of this sort, we in no way wish to suggest that these modes are preferable to using students' active performance in science activities or to using a classroom system where students keep a portfolio with self-evaluation of relevant work. All three of these modes of assessment should mesh in the science classroom. We concentrate here on ways of prompting extended written or oral performances because it is the natural next step to move to from assessing learning solely with multiple-choice items and because it is an efficient way of determining the level of student understanding in day-to-day classroom situations.

The mode of assessment we describe in this chapter uses pencil-and-paper assessments of student learning in a fairly traditional testing situation. However, this is not the only—nor oftentimes the best—purpose for such assessment. Rather, assessment should be viewed as a much broader enterprise. Ongoing, informal assessment using these techniques, for example, is important to planning classroom instruction. It is also a wonderful vehicle for helping students learn to monitor their own learning.

Our primary message in this chapter extends to all levels of science instruction. However, the focus here is on assessment for the elementary and middle grades. This is because we believe that if new science teaching is to influence the attitudes of students toward science in their lives and in the classroom, it is critical to begin early. This said, secondary school teachers should certainly find useful ideas here as well.

TWO CONTRASTING ASSESSMENT EXAMPLES

Between grades 3 and 6, many elementary science programs introduce children to the concepts of endangerment and extinction of species. Dinosaurs are often used as an example of a species that is extinct. Students also learn that some species, such as the African elephant, are threatened with extinction primarily because of hunting, while others are threatened with extinction because man has disrupted their habitats so severely that they no longer can find food. It is in this context that students are usually introduced to the concept of a species. In particular, the implications of the extinction of a species are typically contrasted with the death of one individual in a species.

Here are two typical test items that might appear at the end of a textbook chapter introducing the ideas of extinction and endangerment.

> 1. Which of the following species of animals is now extinct?
> a) The African Elephant
> b) The Dinosaur
> c) The Horse
> d) The Gypsy Moth
>
> 2. True or False: Animals are said to be endangered if they no longer exist.

These are typical multiple-choice and true-false st items. Their function is ostensibly to monitor student learning of what is presented in the text. They are solely information-oriented.

What conclusions can be drawn from responses to these items? Not many, except whether a student can memorize discrete bits of information. But suppose we want to know more. What if we also want to know whether students understand the significance of endangerment and extinction, their causes, and ways that they can be prevented—and can apply this understanding to specific situations in the contemporary world? What sorts of test items will bring these things out?

Here are three different assessment activities that contrast with information-oriented items and have specific uses connected with these different goals:

> 1. When prairie dogs are near farms they eat farmer's crops. Because of this, farmers have killed thousands of prairie dogs. Black-footed ferrets eat prairie dogs. Explain what problem this poses for the ferrets and why this is a problem.
>
> 2. Can you think of any ways that people can save ferrets and still control prairie dogs? Explain what you might do. What would you have to make sure of in order to be sure your solution will work? Is there anything you already know that has bearing on this?
>
> 3. Suppose you were asked to observe the feeding habits of black-footed ferrets so that you could gather some data about this problem. Describe what you would do to make sure that your observations were as accurate as possible and that you brought back data that other people could trust. Write out a plan listing all the things you would think about beforehand.

These are extended-response test items. They represent natural next steps to going beyond multiple-choice test items to expose student understanding and thinking abilities. These items call upon students to perform activities that people engage in as a natural part of doing science. Thus, the test items call for authentic performances, even though the performances are written. We highlight this type of test item to dispel one myth about performance assessment: not all performance tests involve students in doing things such as actually going out and making observations mentioned in the third test item. As long as the task requested is an authentic one, the performance can be written or oral. (Oral responses are more time-consuming to note and assess, but sometimes they are more revealing than written responses, if only because it is easier to ask for clarification and elaboration.)

Note how these assessments are constructed. They contain one or both of the following: open-ended questions or task-specific directions. Both questions and directions are constructed to prompt students to engage in natural scientific tasks. In the case of these test items, the tasks are thinking and communication tasks.

WHY USE EXTENDED RESPONSE PROMPTS?

There is a vast difference between multiple-choice questions and the open-ended extended response items described above. What can student responses to the latter tell us? What specific understandings, skills, and processes do they assess? And how can different student responses be interpreted?

The three extended-response items were designed to provide information about three different kinds of processes:

- Constructing a conceptual understanding of a phenomenon.
- Using information to solve problems and make decisions.
- Using a critical thinking skill (in this case, assessing the accuracy of an observation).

Active Understanding

Typically, understanding in traditional science instruction involves knowing a simple definition. *Active* understanding involves students in:

1. Constructing the concepts and relationships that stand behind simple definitions.
2. Applying this understanding to new situations.
3. Drawing out the implications of the presence of these relationships in such situations.

These are active processes in which students use relevant information they already know in science rather than processes that merely involve remembering words that make up a definition. The elementary grades are not too early to begin to help students develop this deep understanding of the notions of endangerment and extinction.

How can we interpret student answers? Consider one answer to the first question:

> If there aren't enough prairie dogs for the ferrets to eat many of them will starve to death. That's because prairie dogs are their main food. If the farmers kill most or all of the prairie dogs, this will be a big problem because most of the ferrets might die. This would mean that their population would become very low. This would mean that they could become an endangered species. And if they all died they would become extinct. Then there would never be any other ferrets. And maybe this would not just be a problem for the ferrets. If other animals depended on the ferrets for their food, they could become extinct too.

What does this show us about this student's understanding of the concepts of endangered species and extinction? Most striking is an active application of a number of different ideas connected with food chains and population to develop the notion that ferrets could become endangered and even extinct (e.g., "That's because prairie dogs are their main food." "If other animals depended on the ferrets for their food, they could become extinct too."). Notice also that the student affirms the relationship between endangerment and the possibility of extinction ("And if they all died they would become extinct."). In addition, this response shows an appreciation for the potential disaster that would result ("Then there would never be any other ferrets.").

This student not only seems to understand what endangerment and extinction involve and the relationship between them but can actively apply these concepts to a new situation and draw out implications. Notice how important it is to ask students why they think what they do.

Instruction for active understanding challenges and guides students to make the appropriate connection between ideas that yield a basic understanding of a key concept like that of endangered species. This can be accomplished by using a case-study method to present a variety of examples, each of which students study in enough depth so they are able to draw out the implications of applying the new concept to these examples. The examples can be contrasted to cases in which the concept does not apply. Prompting by teachers who ask challenging questions to guide these processes is typical in classrooms geared toward active understanding. Such activities can be hands-on, accompanied by readings, or a combination of both.

Let's look at three other examples of test items that are structured for the purpose of assessing active understanding. Figure 8.2 is a 4th grade example assessing the depth of active understanding students have of the concept of an ecosystem.

The best student responses distinguish between those ingredients necessary for the survival and development of the fish in the tank and those that are incidental to this purpose, though perhaps of interest to humans looking at the tank (like the castle). This reveals students' grasp of the concept of an ecosystem. Such responses show that students can apply the concept constructively to a new situation and explain its implications. This is how their understanding of a key scientific concept is demonstrated. Notice how, like the example of the prairie dogs and ferrets, students are not given the term "ecosystem" in the example (Massachusetts Department of Education 1989).

Here's another example for the 4th grade that tests students' active understanding of the key concept of conductivity in physical science. (It is adapted from an item described in Massachusetts Department of Education 1989.)

> Objects are often made of more than one material for a variety of reasons. Suppose you were asked to make a frying pan out of two different materials. What materials would you use? Why do you select these materials?
> Material 1: Why?
> Material 2: Why?

Students express their understanding of conductivity by explaining why metal is a good substance for the main body of the frying pan while wood or plastic is good for the handle. Such explanations should make explicit the connection between these substances and the transmission of heat.

A more challenging example for 6th grade students relates to the more specialized process of photosynthesis (Massachusetts Department of Education 1989):

> A small tree is planted in a meadow. After 20 years it has grown into a big tree, weighing 250 Kg more than when it was planted. Write a passage that might go into a science textbook explaining where the extra 250 Kg come from.

To summarize, each of these test items accomplishes the following:

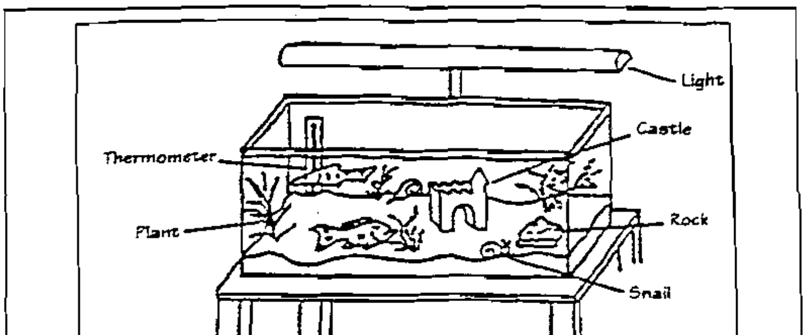
- Gives students new examples to which they can apply a basic science concept.
- Asks them to display this new application by explaining why they emphasize what they do in answering the question.
- Prompts student responses by asking appropriate questions without mentioning these concepts directly.

For your own practice, you may want to construct an open-ended performance assessment item at your own grade level that will yield similar revelations about your students' understanding of one of the following basic concepts: food chains, gravity, convection, plate tectonics, galaxies, predator, heat exchange, antibodies, symbiosis, change of state, or biological system.

Problem Solving and Decision Making

Let's return to assessing students' grasp of endangerment and extinction. Ideally, we want them to understand more than just the implications of endangerment and extinction for a species. We also want them to understand that noting that a species is endangered gives us both a warning and an opportunity to try to do things that will ward off extinction and bring the species back to a flourishing existence. This should be accompanied by a sense of why it might be desir-

FIGURE 8.2
4th Grade Science Prompt



In the picture of the aquarium above, six items are labeled. Which of the six items are important to use in or with an aquarium? Explain why each one you name is important.

able to prevent species from becoming extinct and how accommodation for human needs may be achieved without threatening animal and plant species with extinction. The second test item on ferrets prompts students to do some problem solving about how this might be achieved.

In problem solving in science, we want students to use what they know to construct possible solutions to problems and to determine whether they will work. In so doing, students should think carefully before they judge which solution is best. Predicting the consequences of proposed solutions based on reliable information is crucial in doing this well. Imagining these constructive and weeding-out processes in action as students think through a problem can give us a clue about how to produce an item like the second test item on ferrets. Let's consider a student response to that item. What does it show about this student's problem solving skills?

> I suppose they could move all the ferrets away and feed them something different, while they keep on killing prairie dogs. Or they could protect the ferrets from the animals that kill them so that more of them would survive and they would eat more and more of the prairie dogs. This would solve the farmers' problems for them and they wouldn't have to kill the prairie dogs. Or they could find some other way to keep the prairie dogs from eating the crops.
>
> I'm not sure any of these will work. Maybe the ferrets won't like to eat other things besides prairie dogs. How do we know that they will? And if there are more ferrets and they eat more and more prairie dogs, that may save the farmers for a while, but what then? If there are more ferrets won't the ferrets eat up all the prairie dogs and then not have any food left? And how can prairie dogs be kept from the crops? I learned that they burrow in the ground, so a fence won't help. They'd just go under. Maybe the farmers should move and leave the prairie dogs and ferrets alone.

It is easy to spot this answer as one in which good problem-solving strategies are present. Here are some of the important things we can detect:

- The student *makes use of* information she already knows about ferrets, prairie dogs, and animals in general;
- The student uses this information to construct some possible *solutions*; and
- The student raises significant questions about the effectiveness *of these possible solutions.*

You may wish to note exactly where in this response these important features are displayed as we did in analyzing the student response to the first assessment item. Instruction in skillful problem solvin (and decision making) involves explicitly helping students pay attention to these points in their problem solving, prompting them to reflect metacognitively on how they do this, and providing sufficient opportunities to deliberately practice this way of solving problems using interesting examples. The challenge for the science teacher is to construct interesting problems an create an open classroom environment in which students can grapple with them guided by this organizational strategy (Swartz and Perkins 1990, Swartz and Parks 1994).

The same challenge exists in constructing examples that can be used to assess the level at which students actively engage with problems. Good problem situations for this purpose:

- should not have a simple solution, or a solution that the students can derive by using a simple algorithm; should be authentic problems similar t those we face in the real world and for which we need scientific insight to solve well;
- should call for students to use information they already have;
- should call for students to explore a number of possible solutions; and
- should encourage students to raise important questions about the feasibility of some of these solutions, if not endorse or reject some because of what they already know.

Notice how the strategies used in the second ferret test item accomplish each of these. Students are asked what they might do in order to prompt explicit consideration of possible solutions. They are then asked what they will have to make sure of in order to help them pick the best solution. This prompts them to raise important questions about the feasibility of their solutions. Finally, they are asked whether there is anything they already know that has bearing on how well these solutions will work. This is a direct prompt to get at their sense of the relevance of information they have learned about prairie dogs and ferrets. Finally, this is obviously an authentic problem, yet clearly not a problem with a simple solution.

For your own practice, you might want to construct a prompt that requires students to use this problem-solving strategy around one of the following topics: moving things using simple machines, pollution, exercising for a purpose, colonizing another planet, protection from severe weather, ocean farming, setting up a working ecosystem, or traveling to a distant place to get there by a certain time.

Critical Thinking Skills

A crucial feature of solving problems and making decision in science lies in making critical judgments about the adequacy of possible solutions and the viability of options. This requires the use of a variety of critical thinking skills. These skills are as important in thinking about saving ferrets as they are in setting up a laboratory experiment or constructing a working aquarium. Some of these skills—like being able to make good judgments about the consequences of our options (prediction)—are generic and have broad application outside of science. Others are specific to science content and the procedures used in science, like understanding how to control variables. These skills fall into three basic categories: data collection, analysis of information, and inference.

Prediction is a matter of inference, for example. To teach students to do it well, we should help them base their predictions on good evidence. Classifying things is a matter of analysis. To teach students to do it well, we should help them base their classifications on important similarities and differences among the things classified. The assessment item about feeding habits of black-footed ferrets aims at assessing the skill of data collection and, in particular, determining the reliability and accuracy of an observation. There are, of course, other skills that fall into these categories. For a more comprehensive list see Swartz and Perkins (1990), Swartz and Parks (1994), and Schraer and Stolze (1988).

One of the most important things we want to teach students in science is to gather information from their own observations with care and thoughtfulness. Just giving practice in observation is not sufficient. Students should also learn to discriminate between accurate and reliable observations and those that are not. This key critical thinking skill is generic; it is also useful in assessing eyewitness reports in history, for examples. So when we imagine a student thinking about an observation in order to determine whether it is reliable or unreliable, we want the student to be thinking about things like the following:

- the observation conditions, the use of observation-enhancing instruments, the knowledge that the observer has of what he or she is looking at, and
- the observer's expectations as well as a number of other factors that can influence the accuracy of an observation report.

The third assessment item about ferret feeding habits is a natural way to try to bring out students' understanding of what influences the accuracy of an observation. The performance here is developing and articulating a plan for bringing back accurate observation reports. The following is a response to that item from a student who has learned how to do this well.

> I wouldn't just go and look around. I would make sure that I was close enough to the ferrets to see what they were eating (I might bring binoculars), and I would also make sure that I had looked at some pictures of the different animals around so that I could identify correctly the ones the ferrets were eating. Maybe I should also write down what I saw when I was seeing it instead of waiting 'til later when I might

> forget. That means I'd have to bring a pencil and paper along. And someone else should come too so that we can compare what we are seeing. Then if I tell people that that's what I did they will think that my observations are pretty good ones.

It's very easy to see this is a first-rate response. On the other hand, a student who said simply, "I would go there and look at things," wouldn't be doing very well at this skill.

Instruction in this critical thinking skill involves helping students develop an understanding of what to look for that makes observations reliable by having them work through challenging examples and develop a checklist based on their own collective judgments (Swartz and Perkins 1990, Swartz and Parks 1994). This is not a hard skill to teach, but it does require enough explicit practice to sensitize students to these standards of good judgment about observation reports. (These standards are the basis for any scoring rubric a teacher may develop to fine-tune her assessment of students' mastery of this skill.)

Similar test items can be constructed that reveal how students think about the reliability of written material as a source of accurate information, another generic critical thinking skill. Here's one adapted from an instructional activity connected with library research (Barman et al. 1989):

> Randy was interested in the ocean floor and was thinking about how he could get accurate information about it. He went to the library and got a lot of things that were listed under "oceans." Here are some of them:
>
> 1. "Man's New Frontier" by Luis Marden, from the *National Geographic Magazine*, April 1987.
> 2. "Mysteries of the Ocean" by Patrick Harrington, from the *Magazine for Children*, January 1988.
> 3. "Monsters Under the Sea" in *Great Science Fiction Stories*, 1955.
> 4. "Incredible World of Deep Sea Oases" by Robert Ballard and J. Frederick Grassie, from the *National Geographic Magazine*, November 1979.
>
> Suppose you found out that one of these authors was an explorer who went to the bottom of the ocean in a submarine. What would that indicate about whether he was a good source of information? Why?
>
> Is there anything about these works that would make you choose some of them as more reliable than the others? What?
>
> What other questions would you want to ask about these sources to try to decide whether they were reliable?

Here's another example of an open-ended item designed for 5th graders that can help us determine whether students have mastered skills related to the need to control variables in making comparative judgments in science, a content-specific critical thinking skill (Massachusetts Department of Education 1989):

> A person wants to determine which of two spot removers is more effective. Describe in detail an experiment the person might perform in order to find out which spot remover is better for removing stains from fabrics.
>
> We would like students to provide responses like these:
>
> - We should keep the quantity of the spot removers the same.
> - We should make sure the fabric is the same.
> - The two spots should be as similar as possible (same kind of stain).

Controlling variables is not a difficult concept for students to grasp, but some don't. A similar example can be constructed using well known laundry detergent commercials. What would you want to find out about the circumstances of the experiment to be able to say that the second detergent really does make clothes whiter? Answers we want students to be able to give include: use of the same washing machine, the same speed of wash, the same water temperature, and the same quantity of detergent.

For your own practice, you might want to construct examples that can be used to assess your students on the following critical thinking skills and topics:

- **Accuracy of observation:** reports of laboratory results, of results of an exercise program, or of results of an earthquake.
- **Reliability of secondary sources:** information from old texts, newspapers, or science magazines.

These, then, are three types of verbal performance items that help us assess students' active understanding of basic concepts in science, their ability to use information in problem situations, and their ability to make discriminating critical judgments that are necessary in solving problems well. Analyzing them, as I have done, can enrich our understanding of the deeper processes that are important to teach science.

References

Barman, C., et al. (1989). *Addison Wesley Science*. Menlo Park, Calif.: Addison Wesley.

Massachusetts Department of Education. (1989). *On Their Own: Student Response to Open-Ended Tests in Science*. Quincy: Massachusetts Department of Education.

Schraer, R., and J. Stolze. (1988). "Critical and Creative Thinking." In *Biology: The Study of Life. Teacher's Resource Book*. Newton, Mass.: Allyn and Bacon.

Swartz, R., and S. Parks. (1994). *Infusing Critical and Creative Thinking into Content Instruction: A Lesson Design Handbook for the Elementary Grades*. Pacific Grove, Calif.: Critical Thinking Press and Software.

Swartz, R., and D.N. Perkins. (1990). *Teaching Thinking: Issues and Approaches*, rev. ed. Pacific Grove, Calif.: Critical Thinking Press and Software.