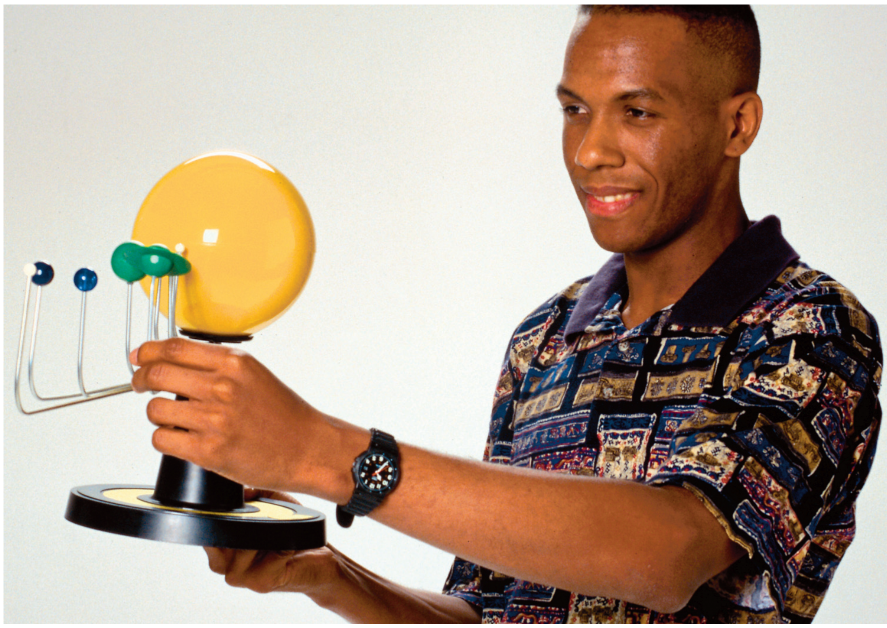
Using Models Effectively

How to guide students through age-appropriate, critical analyses of instructional models

By John Eichinger



Models are crucial to science teaching and learning, yet they can create unforeseen and overlooked challenges for students and teachers. For example, consider the time-tested clay volcano that relies on a vinegar-and-baking-soda mixture for its "eruption." Based on a classroom demonstration of that geologic model, elementary students may interpret the experience to mean that "volcanic eruptions are based on a simple chemical reaction," or "lava is not hot." Students may wonder, "Where do the chemicals come from?" or "How do the vinegar and baking soda mix inside the Earth?"

Other classic models may spawn their own array of naïve notions—the solar system mobile in which all planets are roughly the same size as one another and as the Sun itself, or the quick anatomical visualization that "the human heart is about the size and shape as your fist," or even the seemingly innocuous, simplified textbook diagram of the water cycle depicting the only water source as a lake or ocean. Each may generate incorrect, and frequently unresolved, misconceptions in students' minds.

As adults, we tend to reflexively adjust for the shortcomings of instructional models because they make good sense to us. However, that doesn't mean they'll make good sense to students. We as science teachers can help students analyze the quality and utility of models we introduce in class, so that they have a better sense of empirical reality and thus are better prepared to face real-life situations. What I have found useful is a simple, student-led procedure involving analysis and deconstruction of instructional models. While there is some disagreement about the age at which models can be used to teach science, most believe that models are an integrated process skill suitable for children in late elementary to early middle school years.

A Model for Analysis

I use a practical, straightforward technique to help students analyze instructional models. The analysis can be carried out at the individual, small-group, or whole-class level and consists of three fundamental questions:

- What makes [model example] an effective model, i.e., how does it resemble that which it represents?
- What makes [model example] an insufficient model, i.e., how does it differ from that which it represents?
- How could we improve [model example] as a model?

For example, in the case of the clay volcano we might ask students:

Figure 1.

Sample analyses of three well-known instructional models.

Model Examples	Questions for Model Analysis			
	How is the model similar to that which it represents?	**How does the model differ from that which it represents?**	**What significant misunderstandings might arise in students' minds?**	**How might the model be improved?**
Clay Volcano	Shape is similar to real volcano. Both undergo eruptions.	Uses simple chemical reaction (vinegar and baking soda) for eruption unlike a real volcano, which relies upon high temperature and pressure in the Earth's mantle.	Volcanic eruptions are caused by mixing of simple chemicals. Lava is not necessarily hot.	Use pressure from below (perhaps squeeze a balloon filled with red-colored water attached to a tube into underside of volcano) to generate the eruption.The actual temperature of lava is, of course, not approachable in this model.
Paper Airplane	Has the basic airplane shape (i.e., wings and a fuselage).	Structurally quite different from the real thing (e.g., wings generally provide no actual lift).	Airplanes have flattened wings. Airplanes glide rather than rely on powered flight.	Build a more elaborate model with aerodynamic wings.
Terrarium as Ecosystem	Contains flora, abiotic materials, and possibly fauna.	Smaller, simpler, and entirely sealed.	Ecosystems have little inflow and outflow of flora, fauna, or abiota.	Enlarge and/or increase complexity of the terrarium.

- How is our model volcano like a real volcano?
- How is it not like a real volcano?
- How could we make it more like a real volcano?

Figure 1 offers a brief analysis of three well-known instructional models. Younger children respond well to the use of simple toys as models for analysis and discussion (toy cars, dolls, Lego structures, etc.). For older students and those with more advanced analytical skills, we might ask for more abstract responses. Questions might include, "What sorts of misunderstandings could this particular model lead to if taken too literally?" and "What are the general characteristics of effective and ineffective models?"

More In-Depth Analysis

There are many ways to expand on the basic technique previously described above. For example, conduct a lesson on the use of models using various science models (i.e., an apple representing Earth, an ant made of candy, and a paper airplane). Compare the models, asking the class to consider such questions as, "Which model is most like that which it represents?" "Which model is easiest/hardest to understand? What makes it that way?" or "Which model requires the most explanation from the teacher?"

Another option is to explore an assortment of models relating to one particular subject. For example, when studying the human skeleton, give students access to a labeled skeleton drawing, a student-made pasta skeleton, and a commercially made plastic skeleton. Compare the models, analyzing their individual strengths and weaknesses. Ask such questions as, "Which skeleton model would allow us to best understand the details of a particular bone such as the humerus?" "Which skeleton model offers the best understanding of the bones in the spinal column?" or "What are the advantages and disadvantages of the three models?"

Yet another opportunity for deeper analysis of a model would be to give students a problem to solve that doesn't fit the strengths of that particular model. For example, while small groups explore the clay volcano, ask "Why is lava hot?" then be prepared to lead them into deeper understanding.

As you plan lessons, consider the strengths and weaknesses of the models you select ahead of time. What naïve conclusions, notions, or conceptualizations are possible with each model?

Planning ahead in this sense can help to head off problems before they start or at least to allow you to catch them before they expand and proliferate.

Assessment

The examination of instructional models offers many possibilities in the areas of formative or summative assessment. Challenge students (on an individual or small-group level) to explain how a model represents the topic of study, evaluate a single model for strengths and weaknesses, or compare two models of a single phenomenon. For example, for fifth graders who might be studying the structure of the Earth, you might show them a hard-boiled egg and an orange. Ask, "Which one better represents the layers of the Earth? Why? Can you think of a better model?"

To further develop students' understanding of the pros and cons of model use, be on the lookout for opportunities to allow and encourage students to design, build, and explain their own models, individually, in groups, or as a class. Offer students various materials (recycled cans, cups, paper, bits of Styrofoam, wood, glue, tape, and so forth) with which to build their models.

A Special Case

Computers present a special case. Anything and everything portrayed via computer is, by its very nature, a model. An apple image on the monitor screen is not an apple and will be meaningful to the student in direct proportion to that student's experience with actual apples. Therefore, if computer-based instruction (e.g., science sites, simulations, didactic software) is to be engaging and truly meaningful to elementary students, lessons should first include extensive hands-on explorations of the materials in question. The basic techniques for model analysis outlined above are also appropriate for computer-based instruction in the elementary classroom.

Modeling Scientific Thinking

By challenging students with a few simple questions about instructional models, we give them the opportunity to make sense of what might otherwise be a confusing experience. This technique fosters deeper student thinking; is easily applied to any age or ability level; models scientific thinking, including interdisciplinary investigations; offers life-long skills as it encourages student ownership of concepts; and allows the teacher to assess for comprehension of facts, concepts, and standards in an authentic context.

When is a volcano not a volcano? Ask students to respond to this conundrum and notice how their understanding of scientific concepts and processes deepens.

Connecting to the Standards

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

Science Education Program Standards

Grades K–12
Content Standard: Unifying Concepts and Processes

- Evidence, models, and explanation

Grades K–12
Content Standard A: Science as Inquiry

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

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Resources

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