Introduction

Teaching is both an art and a science. People expect teachers to know their subjects and know how to explain difficult ideas to their students. But teaching is more than explaining; good teaching excites students and makes them want to explore the world around them. Exploring the world is the basis of inquiry science, and to foster inquiry, science ideas need to be intelligible and make sense; they also need to be plausible and believable. But most of all, science ideas should be fruitful in the sense that the ideas, objects, and processes that students explore raise new questions and expose new horizons.

The art of science teaching is seen in the interplay between the teacher's knowledge and the students' questions and "what-if" propositions. Sometimes when teachers think that they have taught an idea well, they are surprised by the quizzical looks on the students' faces. The students don't understand something about the explanation, some of the assumed information is not there, the process is foreign to them, or it is counterintuitive. What can teachers do? They can reexplain the concept and add more background information, and sometimes this works; but if the concept is outside the students' experiences, an analogy or model is a good way to go. Analogies and models are common in everyday life. A road map is a model of the roads and streets in a town or state; a computer is like a person's mind because it can remember and calculate; and a show home represents what your new house could look like.

Analogies and models are thinking tools; they are not fixed representations of objects or processes. When teachers say that a cell is like a tiny box, they are helping their students "see" that a cell has a protective wall all round it, that it comes in a variety of shapes and sizes and can be used for different purposes. When other teachers say that a cell is like a house, they are asking students to think about the things that happen in a house to maintain a family (food input, storage and processing, waste disposal, water flow, parents making decisions, letters sent to friends, etc.). Analogies and models of this kind allow students to adapt the analogy to their knowledge and experiences and see how a cell is like a box, like a house, or like a factory.

This book is written to help teachers creatively explain difficult and abstract concepts. We have included analogies for cells, global warming, multiple analogies for electric current, role plays for chemical reactions and the states of matter, and analogies for plate tectonics and DNA, to name a few. The analogies that teachers use are as varied as the topics we teach in science. For this book, we have collected the popular and reliable analogies that we have found during our work with teachers. Each analogy is explained in detail and then summarized in the Focus-Action-Reflection (FAR) Guide. We hope you find these analogies useful and interesting for you and your students.

Please avoid seeing our analogies and models as definitive: change them, adapt them, and look for ways that they can be improved, and always watch for the point where the analogy or model breaks down. Most of all, encourage your students to construct their own analogies and join in with them as they create and develop their analogies and models.

The FAR Guide

The book has two central themes: first, using analogies is an interesting and engaging way to explain science concepts. Analogies make difficult and abstract concepts familiar by comparing them to everyday objects and experiences. For analogies to work, the analog or everyday object or experience must be familiar. If a particular analog is not familiar, substitute an example that is well understood by your students.

Second, the ways in which the analog is *like* the science concept and the ways in which it is *unlike* the science concept should be discussed with your students. Teachers sometimes avoid analogies because they engender alternative conceptions, which arise when the analogy is taken too far or too literally.

The FAR Guide was designed to enhance the presentation and interpretation of analogies. The acronym stands for

Focus—Be sure of what your students know and why you want to use the analogy;

Action—Be sure to check that your students understand the everyday object or experience you plan to use and ensure that you always discuss how the analog is *like* the science concept and how it is *unlike* the concept; and

Reflection—Reflect on the analogy's usefulness; ask yourself, "Do I need to revisit this explanation and are there better ways to use the analogy next time I teach this content?" Maybe you will decide to use a different analogy next time. This is good teaching.

The steps in the FAR Guide for teaching with analogies are summarized in the following table and elaborated in Chapter 2.

The FAR Guide

Focus	
Concept	Is it difficult, unfamiliar, or abstract?
Students	What ideas do the students already know about the concept?
Analog	Is the analog something your students are familiar with?
Action	
Likes	Discuss the features of the analog and the science concept. Draw similarities between them.
Unlikes	Discuss where the analog is unlike the science concept.
Reflection	
Conclusions	Was the analogy clear and useful or confusing? Did it achieve your planned outcomes?
Improvements	In light of outcomes, are there any changes you need to make next time you use this analogy?

We hope your teaching with analogies is exciting and productive.

Teaching With Analogies in a Standards-Based Classroom

Teaching with analogies can be fun and motivating for students, and research suggests it also enhances student learning of scientific concepts. However, teachers are busy people held to account for meeting their students' learning outcomes. This often involves meeting national educational standards devised by educational authorities. Meeting some standards is problematic, and teachers often have to consider exactly how they might meet such standards. For straightforward concepts and ideas, conventional teaching approaches may work well, but as most teachers know, many concepts are challenging, especially those that form the basis of this book. The analogies we provide here were not developed arbitrarily; they were developed to address subjects the literature suggests teachers find difficult to teach.

The analogies presented in this book provide an excellent and efficient means of addressing science standards for a variety of topics. To show how teachers can use these analogies to meet educational standards, for each analogy presented in Part II of the book we have linked the concepts to some national standards. We have chosen the U.S.-based National Science Teachers Association's recommended standards (National Academy of Sciences, 1996) and linked the concepts to specific standards at a variety of grade levels, mainly the Science Content Standards. You will see that the same analogy can be used to satisfy standards at different levels and for different topics. So, for example, the Shared Water Flow Analogy can be used for Science Content Standard B Physical Science, at Grades 5–8 for the topic "energy is transferred" and "energy is an important property of substances and . . . most change involves energy transfer." But it also can be used for Physical Science at Grades 9–12, where it can be used to explain Ohm's Law and moving electric charges. This reflects the versatility of analogies as teaching tools. Of course, you should exercise your judgment as to how a given analogy best suits your teaching demands and the learning needs of your students.

The links to the National Academy of Sciences (1996) standards we have provided are logical to us, but again you should exercise your judgment with analogy use as with any pedagogical tool. You may see a better fit with another standard that you may have struggled to meet. Likewise, the analogies here can be linked to a variety of other national standards, and the links provided here thus serve to illustrate how analogies can be used to meet national educational standards rather than how they must be used.