On Teaching Science

Principles and Strategies That Every Educator Should Know

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Strategy 6: Use Plain Language

The following pages are excerpted from Chapter 6 of *On Teaching Science*. Learn more at www.OnTeachingScience.com.

claims that a pen would float away if you dropped it on the Moon; when asked why the Apollo astronauts didn't float away, he replies, "Because they were wearing heavy boots." The story is posted on numerous web sites (try a search on "heavy boots on the Moon"), but I have not been able to track down its original source.

Simple demonstrations and personal paradoxes are particularly good ways to dispel misconceptions, but they are not always possible. In such cases, you'll need to find some other way to get students to recognize the errors in their thinking for themselves. Sometimes it's just a matter of asking students to think about whether some idea really makes sense. My astronomy textbook co-author Megan Donahue tells a story about growing up in Nebraska and being told that the sky is blue because of reflection from the oceans, which clearly didn't make sense for such a deep inland location. A common misconception requiring an extra step is the well-known one in which students think that moon phases are caused by shadows from Earth. To dispel this one, you first have to get students to realize that the Moon orbits Earth. Once you do that, you can show how most positions in the orbit mean that no shadow from Earth could possibly hit the Moon, at which point you can begin to talk about (and demonstrate) the real cause of the phases.

Not all misconceptions are as easy to dispel as the ones I've given as examples here, but the bottom line should be clear: Unless you first dispel a student's misconceptions, there's little chance that you'll be able to teach that student a correct understanding.

Strategy 6

Use plain language.

Open up an introductory college science textbook and start counting the number of bold or glossary terms that are likely to be unfamiliar to students when they first enroll in a class. Although there is a large range, most college-level textbooks have a least several hundred such terms, and some (particularly in biology) have upwards of 1,500. Amazingly, this turns out to be *comparable to or greater than the number of vocabulary words that students typically learn in a first-year foreign language course*. Given that most students find science itself to be unfamiliar, the large amount of jargon clearly makes their task of learning it far more difficult. In essence, it's as though we are attempting to teach introductory students an unfamiliar subject (science) in what to them sounds like a foreign language. The situation in K–12 education is only marginally less severe.

If all this jargon were helpful to conceptual understanding, then we might be justified in expecting students to learn it. But while some jargon is clearly necessary, in many cases we use jargon that no one besides specialists in a particular scientific discipline ever really needs to know. For an astronomical example, ask yourself whether you could identify:

- *scarps* on Mercury
- *lunar regolith*
- the distinction between *chondrites* and *achondrites*

The italicized terms are all commonly found in astronomy textbooks intended for nonscience majors, yet few people besides planetary geologists have any idea what they mean. Indeed, when I have presented these terms in talks to college astronomy faculty, many of whom have taught out of textbooks that use these terms, I've still found it rare to find anyone who knows all of them. Given that most professional astronomers don't even know what these terms mean, why would we ever expect nonmajor freshman or high school students to learn them?

In the vast majority of cases, replacing jargon with plain language has no downside and a tremendous upside in making it easier for students to focus on real scientific concepts. The only exceptions are when the jargon has entered the common vernacular, so that students are likely to hear the same terminology in news reports, and when you are teaching upper-level students who need to become conversant in the language of their discipline. With that in mind, I'll offer a few suggestions on dealing with different types of jargon, along with examples of each. I apologize in advance for giving many more examples here than in the rest of the strategies, but I think they are particularly illustrative in this case.

NOTE: JARGON REDUCTION IS *NOT* "DUMBING DOWN" Back in the section on the one key to student success, I noted the pressure to lower expectations and dumb down courses and textbooks. Some of you may wonder if the idea of reducing jargon is an example of this very type of dumbing down. My answer is no, because I don't believe that the jargon serves to enhance understanding. In fact, I believe that reducing jargon actually allows us to *raise* expectations, because by removing the foreign language aspect we have more time available to cover the breadth and depth of the scientific subject matter. Also worth noting: Students and others often use jargon to try to give people the impression they know more than they do; reducing jargon can therefore expose how much or little is truly understood.

NOTE: PLEASE "DNUA" Do you know what I mean when I say "DNUA"? (And how do you pronounce it?) Probably not, because I just made it up: It's my new acronym for "Do Not Use Acronyms." The fact is, acronyms are rarely helpful, because unless they are among the rare ones that have made it into the common vernacular (such as radar, laser, or NASA), they are just another form of jargon that students have to learn — and in the case of acronyms, they are easily replaced by writing the words out. Sure, it takes a little more typing or a little more breath for me to say "do not use acronyms" than it does for me to say "DNUA," but that's a small price to pay for making sure that you'll know what I'm talking about. The same is true for virtually all other acronyms. So as part of your general jargon reduction effort, please reduce your use of acronyms. The closer you can get to zero use, the better. And when you just can't avoid them — for example, you'll find numerous places in this book where I've used the acronym STEM (science, technology, engineering, and mathematics) — at least put the full term in parentheses once in a while, so as to remind students of what you mean.

Translate When Possible: In many cases, the jargon we use in science can be translated simply into plain language, which is exactly what you should do in those cases. Consider the three terms I gave you above, but now with translations:

- *Scarps* are just a fancy name that planetary geologists like to use for the long, tall cliffs that are prevalent on Mercury.

  NOTE: A TRUE STORY Once when I gave my talk to a faculty group that included several geologists, one of the geologists took exception to my translation, explaining that scarps are not really quite the same as cliffs. Another geologist then stood up and said that he agreed they were not quite the same, but disagreed with the first geologist on the reason. A third then stood up and said that actually, he thought of them as synonymous. The debate continued for several minutes, by which time I think they all agreed that whatever the distinction might or might not be, it was not something that freshman non-majors needed to know.

Figure 7. Familiar photos of astronaut footprints make it clear that the Moon's surface is covered by a powdery soil. Telling students that this powdery soil is technically called the lunar regolith does not in any way enhance their understanding of the lunar surface; in fact, it reduces their understanding by forcing them to learn an unnecessary term that they're almost guaranteed to forget later anyway. (NASA, *Apollo 11*)

- *Lunar regolith* is a fancy name for the powdery lunar soil in which the astronauts left their footprints (Figure 7).
- *Chondrites* and *achondrites* are types of meteorite. The names describe a particular geological characteristic (the presence or absence of small, round *chondrules*), but the former are thought to represent primitive material that condensed in the very beginning of the solar system's history, while the latter represent meteorites that were once pieces of larger asteroids (either pieces chipped off an asteroid's surface in an impact or remnants of an asteroid that shattered in a collision) and that therefore have undergone geological processing since the solar system first formed. Given all that, it's much simpler to refer to the chondrites as "primitive meteorites" and the achondrites as "processed meteorites," since those terms directly reflect the differences between them.

Before we move on to the next jargon type, it's worth thinking about what happens if you *don't* use simple translations when they are available. Just as it takes years to become fluent in a foreign language, it takes years to become totally comfortable with scientific jargon. During the short time you have students in your class, even those who memorize the meaning of a piece of jargon will inevitably go through a mental translation every time they hear it. For example, every time you say "scarp," the student will need to pause and recall that it means "cliff" — and during that mental pause, they may miss something else important that you were trying to teach them.

Seek Simpler Choices: Translations like those above are available only when a term has a direct counterpart in plain language. In science, there are many cases in which a word goes with a concept that is likely to be unfamiliar, which means you won't find a direct translation. Nevertheless, there are often choices of available jargon in such cases, and you should always seek the simpler choices. Again, I'll offer some astronomical examples, and I'm sure you can find similar examples in whatever subject you teach.

- Professional astronomers often measure distances to stars in units called *parsecs* and distances to galaxies in *megaparsecs*. But these can be easily converted into *light-years* and *millions of light-years*, respectively, because 1 parsec = 3.26 light-years. Light-years are still a form of jargon since they are not a familiar unit from everyday life, but the name itself helps explain what the unit means (it is the *distance* that light travels in one year through empty space, which is roughly 10 trillion kilometers, or 6 trillion miles). In contrast, the term *parsec* is utterly meaningless to most people, which makes it a less desirable choice of jargon. (In case you are wondering, the term *parsec* is short for "parallax second," and it is geometrically defined as the distance at which an object would have an annual parallax shift in our sky of one arcsecond.)

  NOTE: PAY ATTENTION TO JARGON IN THE MEDIA This particular example is illustrative of how the common vernacular can come into play. Until a little more than a decade ago, virtually all astronomers quoted Hubble's constant in units of kilometers per second per megaparsec, and as a result, those were the units that you generally saw in news sources such as *The New York Times*. That has since changed, however, and news sources now usually ask scientists to give Hubble's constant in units of kilometers per second per million light-years. So while teaching nonmajor students the jargon of parsecs and megaparsecs may have been justifiable when they were likely to see it in the media, there's no longer any good reason for them to learn the terms.

- Traditionally, the balance between gravity and pressure in a stable astronomical object has been called *hydrostatic equilibrium.* (The term is also used for Earth's atmosphere and for other fluids.) But this term confuses students a great deal, because it has nothing to do with any of the mental bins in which they are likely to try to fit it, such as those for water, hydrogen, or static electricity. A number of years ago, a couple of prominent astronomers wrote a book in which they replaced the term "hydrostatic equilibrium" with the term *gravitational equilibrium* (Begelman, Mitchell and Rees, Martin, *Gravity's Fatal Attraction*, Scientific American

Library, 1996). It's still a form of jargon, but note how much easier it is to remember that gravitational equilibrium is a balance between gravity and pressure. Indeed, it has an added advantage: The standard jargon for what happens to a star as it shrinks due to its own gravity is *gravitational contraction*, so it makes perfect sense to think that once gravity is offset by pressure, the star settles into a state of gravitational equilibrium.

- In the first edition of Taylor and Wheeler's classic textbook on relativity, called *Spacetime Physics*, there was a lot of discussion of *inertial reference frames*. In the second edition, that term was replaced by *free-float frames*. Again, the new term is still a form of jargon, but it has an underlying sense to it; after all, the defining characteristic of an inertial reference frame is that it is a reference frame in which you would float freely.

NOTE: WHEN JARGON IS UNAVOIDABLE, POINT OUT WORD ROOTS AND ETYMOLOGY The Latin origin of the term *inertia* (which means "inactivity") reminds me that while I'd like to see this particular term discarded, there are other cases in which jargon is unavoidable, and in those cases we can often help students by pointing out its roots or etymology. A couple of simple examples from biology: (1) The structures in the ear called *scala* get that name because *scala* means "ladders," and they look somewhat like ladders. (2) The term *phage* comes from a word meaning "glutton" or "eater," which helps explain why a *bacteriophage* is not itself a bacterium but rather a virus that infects (and often kills) bacteria.

- Professional astronomers talk about different types of supernovae as Type I or Type II, with the first category further subdivided into Types Ia, Ib, and Ic. The types have historical pedigree in describing characteristics of different supernova spectra, but today we think we have a pretty good understanding of supernovae. This understanding tells us that they come in two basic types: a type that occurs when a high-mass star explodes and a type that occurs when a white dwarf (an object that is the remains of a low-mass star that has died) explodes. So why not just call the two types "massive star supernovae" and "white dwarf supernovae?" It's much easier than trying to remember the correspondence to the "types," especially since that correspondence turns out to be complex: Type Ia supernovae are the only ones thought to be from white dwarfs, which means that Types Ib, Ic, and II all represent essentially the same type of progenitor.

NOTE: PLEASE DON'T "TYPE"-CAST SCIENCE I'll go further and give you a general rule about "types": The terms "Type I" and "Type II" are so overused throughout science that they can never be helpful to students. For example, depending on your field of study, you may deal with Type I and Type II errors, Type I and Type II ionic compounds, Type I and Type II muscle fibers, Type I and Type II schizophrenia, Type I and Type II diabetes, and even Type I and Type II (and Type III) civilizations!

- As you may notice from my note above about "types," scientists often overuse favorite words. For astronomers, one of these favorites is "dwarf." There are dwarf planets and dwarf galaxies, brown dwarfs, white dwarfs, black dwarfs, red dwarfs, yellow dwarfs, and more. Even worse, most of these different dwarfs have little in common with one another. In a few cases, such as for brown dwarfs (objects that are in between a large planet and a small star) or white dwarfs (which are a type of dead stellar core), there really aren't any alternative terms, so we're stuck with them. But red dwarfs, for example, are ordinary stars that are relatively small in size and red in color. Because we already have a piece of jargon that students learn for ordinary stars — they are called *main-sequence stars* — there's no reason to use the term "red dwarf," since such a star is just as easily and much more clearly described as a "red main-sequence star." (I consider the jargon "main-sequence stars" to be acceptable, both because there's no easy replacement and because it emphasizes an idea that students really do need to learn in astronomy, which is that all such stars form a well-defined sequence when they are plotted on a graph of temperature versus luminosity [the "H–R diagram," another piece of jargon which I'll say more about below].)

NOTE: A DWARF QUIZ Try this question: *What color is a brown dwarf?*

a. brown
c. magenta
b. green
d. dwarfish

This is the first question from a short quiz that I wrote a few years ago, when I became so annoyed by the overuse of the term "dwarfs" that I felt I needed something to show the insanity of this jargon. You may find the full quiz entertaining, so I've included it as Appendix 3. And in case you are wondering, the correct answer to this first question is c (magenta) — really!

It’s Nice to Honor Them, But…: Another common form of jargon in science arises from the habit of naming things in honor of their discoverers (or at least the people who first published them). We say “Newton’s laws” and expect people to know we mean the laws of motion, or “Kepler’s laws” and expect people to know we’re talking about planetary motion, or “Maxwell’s equations” with the expectation that they’ll know we’re talking about equations governing electromagnetism, or “Magellanic clouds” and assume they know we’re talking about two small galaxies that were known to people in the Southern Hemisphere for millennia before Europeans decided to name them for Magellan. These examples at least involve somewhat famous names, but here are some others you’ll find in many introductory astronomy books: Kirchhoff’s laws, Herbig-Haro objects, Seyfert galaxies, Zeeman effect, Chandrasekhar limit, Hertzsprung-Russell or H–R diagram, and Oort cloud (which has essentially nothing in common with the Magellanic clouds). None of these names are likely to be familiar to anyone outside of the professional astronomy community.

I suppose it’s nice that we like to hand out scientific honors, but learning all these names is as useful to helping students learn science as memorizing state capitals is to helping them understand U.S. history. So while we all probably hope something will be named for us someday, we’ll do our students a big favor if we do our best to say what we mean instead of dropping names.

There are some cases in which we are probably stuck with the names because they are so famous, such as with Newton or Kepler or Maxwell, but even then we can try to be clearer by saying, for example, “Newton’s laws of motion” (rather than simply “Newton’s laws”) or “Maxwell’s equations of electromagnetism.” There are other cases in which there are not yet any widely recognized alternatives; for example, I’m unaware of any easy replacement term for the “Oort cloud,” which refers to the vast space around our solar system that is thought to be inhabited by trillions of comets, and the H–R diagram seems an acceptable shorthand for the alternative of having to repeatedly say “a diagram that plots stars by temperature on the horizontal axis and luminosity on the vertical axis.” But there are many other cases in which there’s an easy work-around; using a few of my earlier examples, the Chandrasekhar limit can be called the “white dwarf limit” (because it is a limit on the mass of a white dwarf), the Zeeman effect can simply be described as the splitting of spectral lines due to a magnetic field, and Kirchhoff’s laws are laws describing how spectra form. In these and similar cases, the work-arounds allow students to focus on the concepts rather than on the "stamp collecting" of names.

Be Accurate, But Not Persnickety: Even while we reduce jargon, I still believe it's very important that we be accurate with our terminology in science. For example, we should not allow students to mix up terms like weight and mass, even if they are commonly interchanged in everyday language. Nevertheless, there are cases where complete technical accuracy just adds to the confusion, and in those cases I think we can make reasonable judgments on the side of clarity. Three examples that, while from astronomy, are likely to be familiar to almost everyone:

- What do you call a small rock floating in space that comes crashing down to Earth? Technically, while it's in space, it's a *meteoroid*; on its way down, it becomes a *meteor*; and the remnant piece that hits the ground is called a *meteorite*. But movies and popular culture often call it a "meteor" in all three cases, and is there really any harm in that? Perhaps it's worth a couple sentences in class (or in a textbook) to explain the technical differences to students, but I wouldn't give a test question on it.
- Comets have a similar problem. The word *comet* comes from a Greek word for "hair," which means that an icy object technically becomes a comet only when it is close enough to the Sun for its ices to vaporize and form a tail (the "hair"). For that reason, the objects that become comets are technically *not* called comets when they are far from the Sun, but we sure confuse students when we tell them that an icy object gradually "becomes" a comet as it approaches the Sun (and then stops being one when it returns to being far away from the Sun). Doesn't it make much more sense to refer to all icy objects that could in principle grow tails as comets, no matter whether they are currently frozen and far from the Sun or currently approaching the Sun and forming a tail? An added advantage of this approach is that it means that Pluto is really just a big comet, which is a lot more meaningful than the whole debate about what should be called a planet.
- Speaking of planets, I've been surprised by how much time some teachers spend debating the demotion of Pluto. Nature doesn't always have clear distinctions between categories, and the distinction between "large comet" (or asteroid, if it's rocky), "dwarf planet," and "planet" is not really any more important than the distinction between "creek,"

"stream," and "river." Let's spend our time focusing on the science of the solar system, not on battles over naming.

NOTE: WHEN EARTH WASN'T A PLANET It's worth pointing out that the word *planet* has been through several past redefinitions. The word itself comes from the Greek for "wanderer" and the seven planets of ancient times were the seven objects that appear to wander among the constellations — which means that the Sun and Moon were originally considered planets, while Earth was not.

Be Clear When Jargon Conflicts with Common Usage: There are some cases in which scientific jargon actually uses plain-language terms, but with a different meaning than they have in ordinary speech. In those cases, we need to be especially careful to be sure that students understand what we actually mean.

The most notable case is the word *theory*. In everyday speech, the term is often used synonymously with *hypothesis*, but in science the two ideas are very different. After all, when creationists say that evolution is "only a theory," they don't intend to mean the same thing that we mean by a theory in science, which is a broad-based model that successfully explains a vast body of evidence and that has been repeatedly tested and verified. I think the best way to deal with this type of situation is to be very clear in explaining the idea of a scientific theory to students, both when we first introduce it and whenever the term arises in any of our discussions.

NOTE: WHY I STILL LIKE THE TERM "THEORY" A few of my colleagues (most notably, planetary scientist David Morrison) have suggested that the term "theory" is so misunderstood that we should simply avoid it; for example, we could simply refer to "evolution" rather than the "theory of evolution." There is some merit to this idea, but I also see some risks. For example, in helping students understand the nature of science, I think it is important to distinguish between the "observational facts of evolution" — meaning the fossil record with its clear demonstration that evolution occurs — and the "theory of evolution" that describes how evolution proceeds through natural selection. The former is not subject to any scientific debate at all, while the latter is continually being refined as we learn more about the molecular basis of evolution and the precise timing of evolutionary changes. If we simply say "evolution," we lose the ability to make this important distinction.

Similar clarity is needed in cases where jargon tends to evoke misconceptions. For example, the name "theory of relativity" has tended to make people think that it says "everything is relative," when in fact it refers specifically to the relativity of motion. Again, the best defense in this case is to let your students know that it does *not* mean that everything is relative, and then explain what it does mean.

There are many more cases in which we tend to use terms in science with a different meaning than they typically have in everyday life. One of the best lists I've seen of such terms was published in the article "Communicating the Science of Climate Change," by Richard Somerville and Susan Joy Hassol (*Physics Today*, Oct. 2011), which my textbook co-authors and I have modified and expanded into Table 2 on pages 100–101.

Don't Make a Bad Jargon Situation Worse: My final comment on jargon is that, given how bad the jargon situation already is, we should work hard to avoid making it worse. Unfortunately, the pressure tends to work in the opposite direction, because whenever scientists (including those who do research in science education) learn something new, there's a great temptation to assign a piece of jargon to it. In addition, particularly for discoveries that get press coverage, there's often a temptation to make up "cute" new names that may get great media play but that probably don't help student or public understanding. I'll give you a few recent examples of new jargon that really should *not* have been introduced:

- "The God particle." In case you missed it, this is the media-blessed name for the Higgs boson, a subatomic particle whose existence was predicted decades ago (by Peter Higgs) but was only recently confirmed through experiments at the Large Hadron Collider in Europe. But the name "God particle" is truly egregious: Not only is it preposterous to presume that this particle is so important that it equates to God, but the term runs completely counter to our goal of showing the public that science and religion are *not* in conflict. Just call the particle the Higgs boson — it's still a piece of jargon, but the particle has to have some kind of name, and in this case the name "Higgs" is probably as good as any.
- "The Goldilocks zone." This term has recently become popular as a way to describe the region around a star in which an Earth-like planet (e.g., a planet with liquid-water oceans on its surface) could conceivably form. Both scientists and the media now routinely use this term over the formerly favored "habitable zone," presumably because it's kind of cute to

(*continues after Table 2*)

Table 2. Scientific Usage Often Differs from Everyday Usage

This table is adapted from the article “Communicating the Science of Climate Change,” by Richard Somerville and Susan Joy Hassol (*Physics Today*, Oct. 2011).

Term	Everyday meaning	Scientific meaning	Example
model	something you build, like a model airplane	a representation of nature, sometimes using mathematics or computer simulations, that is intended to explain or predict observed phenomena	A model of planetary motion can be used to calculate exactly where planets should appear in our sky.
hypothesis	a guess or assumption of almost any type	a model that has been proposed to explain some observations, but which has not yet been rigorously confirmed	Scientists hypothesize that the Moon was formed by a giant impact, but there is not enough evidence to be fully confident in this model.
theory	speculation	a particularly powerful model that has been so extensively tested and verified that we have extremely high confidence in its validity	Einstein’s theory of relativity successfully explains a broad range of natural phenomena and has passed a great many tests of its validity.
bias	distortion, political motive	tendency toward a particular result	Current techniques for detecting extrasolar planets are biased toward detecting large planets.
critical	really important; involving criticism, often negative	right on the edge	A boiling point is a “critical value” because above that temperature, a liquid will boil away.
deviation	strangeness or unacceptable behavior	change or difference	The recent deviation in global temperatures compared to their long-term average implies that something is heating the planet.

Table 2. (*continued*)

Term	Everyday meaning	Scientific meaning	Example
enhance/ enrich	improve	increase or add more, but not necessarily to make something "better"	"Enhanced color" means color that has been brightened. "Enriched with iron" means containing more iron.
error	mistake	range of uncertainty	The "margin of error" tells us how closely measured values are likely to reflect true values.
negative feedback	poor response	a self-regulating cycle	The Sun's fusion rate is steady because if it were to go up, negative feedback would cause it to go back down.
positive feedback	good response, praise	a self-reinforcing cycle	Gravity can provide positive feedback to a forming planet: Adding mass leads to stronger gravity, which leads to more added mass, and so on.
state (as a noun)	a place or location	a description of current condition	The Sun is in a state of balance, so that it shines steadily.
trick	deception or prank	clever approach	A mathematical trick solved the problem.
uncertainty	ignorance	a range of possible values around some central value	The measured age of our solar system is 4.55 billion years with an uncertainty of 0.02 billion years.
values	ethics, monetary values	numbers or quantities	The speed of light has a measured value of 300,000 km/s.

think of the region in which a planet could be habitable as the "just right" region around a star in the same way that Goldilocks found the baby bear's porridge, chair, and bed to be "just right" in the English fairy tale known as "Goldilocks and the Three Bears." The problem, however, is that not everyone knows the Goldilocks story; in fact, it's rarely known to people whose native language is not English, and often unfamiliar to students with immigrant parents. Given that one of our goals is to increase the diversity of students entering science, it's crazy to introduce a new term that will make no sense to them when we have a perfectly good term (*habitable zone*) already.

- "Ice giants." Recently, some planetary scientists have taken to referring to the planets Uranus and Neptune as "ice giants." Their reasoning is as follows: These planets have traditionally been grouped with Jupiter and Saturn as the "gas giants," a term that makes at least some sense because Jupiter and Saturn are composed primarily of hydrogen and helium, which we usually think of as being gases. However, the compositions of Uranus and Neptune are actually dominated by hydrogen-based compounds such as water (H_2O), methane (CH_4), and ammonia (NH_3) — and these are substances that can be frozen to make ices on Earth (and are ices in comets and on many moons). But here's a simple fact: Except perhaps for some snowlike particles in their clouds, *there is essentially no ice at all* inside either Uranus or Neptune; rather, the high pressures and temperatures in the planetary interiors compress these hydrogen compounds into other phases (some familiar from Earth and some not). So with apologies to my friends who like the term, using the term "ice giant" for planets with virtually no ice at all makes virtually no sense.

NOTE: SO WHAT SHOULD WE CALL URANUS AND NEPTUNE? While "ice giants" is a terrible term, other options are not all that great either, especially since discoveries of extrasolar planets have shown us that planets come in a wider range of types than we had recognized when we knew only the planets of our own solar system. But until we get a better understanding of planetary types, I'd advocate sticking with what has long been an alternative to "gas giants," which is the term *jovian planets* (*jovian* means "Jupiter-like"). One reason I prefer this term is that just as Uranus and Neptune really don't contain ice, Jupiter and Saturn don't really contain much gas, because the high-pressure conditions found throughout most of their interiors compress the "gases" into liquid, metallic, or other strange forms. But in addition, the term "jovian" can be thought of in terms of planetary formation, and the planets Jupiter, Saturn, Uranus, and Neptune are all thought to have formed in a similar way that is distinct from the way the four terrestrial ("Earth-like") planets formed. (The outer planets are thought to have formed around large "cores" made of ice, rock, and metal that had condensed from the cloud of gas that gave birth to our solar system, and these cores were massive enough for their gravity to then collect some of the abundant hydrogen and helium gas that surrounded them. The differences between Jupiter/Saturn and Uranus/Neptune can then be traced simply to the amounts of the hydrogen and helium they captured.)

- "Flipped classrooms." OK, I'm guilty of having used this one in this book, though you'll notice that I always put it in quotes and defined it clearly when I first introduced it. But the truth is, I used it mainly because I expect that a substantial fraction of the people reading a book like this one will be familiar with it and will expect to see it, not because it's necessarily a good idea. For example, think about the image that this term must evoke when nonteachers hear it: Do they picture a teacher standing in the back of the class instead of the front, or tables and chairs placed upside down, or students hanging from the ceiling? I also dislike the term because it makes it sound like some new idea, but as I pointed out earlier, many great teachers have in essence employed this strategy for a very long time. Personally, I'd advocate simply talking about the value of having students come to class prepared for activities and discussions.

Strategy 7

Challenge your students.

I'll keep this one short, because while it's very important, it's really just a restatement of ideas we've discussed earlier. You are a science teacher because you love science. You undoubtedly find it amazing, fascinating, even awe-inspiring. If you convey your passion for science to your students, they'll love it too. In fact, they'll love it so much that they'll want you to challenge them, and they will rise to meet any reasonable expectations you set for them, as long as you follow the other strategies and practices of good teaching that we've discussed.