Strategies for Teaching (Math and Science)

Human history becomes more and more a race between education and catastrophe.
— H. G. Wells, 1920

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Outline:

- 1 Key to Student Success
- 3 Big Picture Ideas about Teaching
- 5 General Suggestions for Successful Teaching
- 7 Pedagogical Strategies for Math/Science Teaching
- Questions/discussion

Definition

Teaching The transmission of knowledge *and* of the means to acquire additional knowledge from one person to others.

One
Key to Student Success

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Studying Active engagement of the brain.

E.g., can include lecture, videos, etc., *if* you are engaged.

And can exclude homework, labs, reading *if* they are done mindlessly.

One
Key to Student Success

You cannot learn without studying.

Full-time students, time spent studying (outside class):

- 1960s: ~25 hours per week
- Today: ~14 hours per week

→ Unless today's students study far more efficiently (unlikely given distractions), then **they are *learning less* than counterparts of the past**.

One
Key to Student Success

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Multitasking (noun)

doing several things at once, all of them poorly.

Three
Big Picture Ideas about Teaching

1. *You can't actually "teach" anything to anybody… Rather, a good teacher enables students to learn something for themselves.*

in other words …

This doesn't work…

Education is not the filling of a pail, but the lighting of a fire.

— William Butler Yeats

Three Big Picture Ideas about Teaching

1. *You can't actually "teach" anything to anybody…*
2. *Brains are brains.*
   - Children and grownups all learn the same way…
   - … it's just that as we get older, our brains are filled with more prior knowledge (or prior misconceptions).

Example: Everyone shares issues of *scale*

Three
Big Picture Ideas about Teaching

1. *You can't actually "teach" anything to anybody…*
2. *Brains are brains.*
3. *People have been teaching successfully for thousands of years.*

   The difference today is:

   - in the past, teaching was usually one-on-one, educating a small % of population
   - today, we hope to "mass produce" education for all

Five
General Suggestions for Teaching

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No matter how good your textbook…

No matter how effective your use of class time…

*Teaching success depends primarily on **motivating** students to make good use of study time outside of the classroom.*

(*and how do you do that?)*

Major components of study time:

- **reading**
- **homework**
- **exam preparation**

from *How to Succeed in College Classes*[*]

If your course is:	**time for reading the assigned text (per week)**	**time for homework assignments (per week)**	**time for review and test preparation (average per week)**	**total study time (per week)**
3 credits	2 to 4 hours	2 to 3 hours	2 hours	6 to 9 hours
4 credits	3 to 5 hours	2 to 4 hours	3 hours	8 to 12 hours
5 credits	3 to 5 hours	3 to 6 hours	4 hours	10 to 15hours

[*] **Appears in all my textbooks; or freely download from my web site.**

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   Class time: motivation and guidance

   Assignments: Reading, homework, exams

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3. *Teach for the long term by focusing on three linked goals: **education**, **perspective**, **inspiration**.*

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4. *Set high but realistic expectations (and spell them out clearly).*

5. *Don't take it personally.*

Seven
Pedagogical Strategies for Math/Science

Strategy 1. Begin With and Stay Focused on the Big Picture

Premise: Science is filled with interesting facts and details, but they'll be absorbed only if they are fit into "big picture" of the subject matter.

Strategy 1. Begin With and Stay Focused on the Big Picture

Examples of the Big Picture:

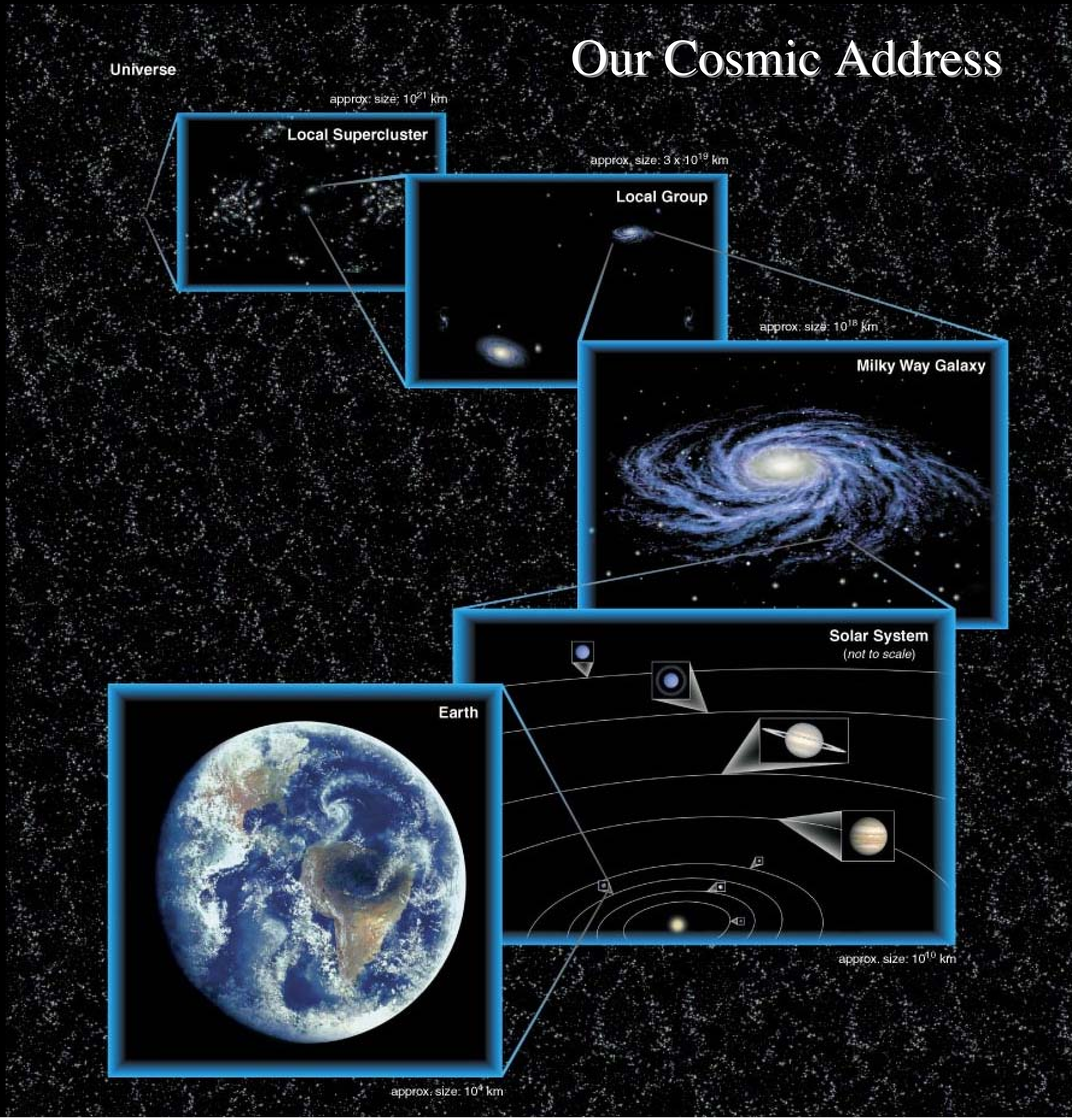
- All science: Nature of science; science vs. nonscience (next slide)
- Astronomy: Seeking to understand our place in the universe.
- Biology: Seeking to understand the nature and evolution of life.
- Physics: Seeking to understand how we interact with physical surroundings.
- Math: Seeking tools that help us understand the issues we face in our daily lives.

Strategy 1. Begin With and Stay Focused on the Big Picture

Example:

"Which one is bigger?"

Our Cosmic Address



Purposes of Science

- *a way of distinguishing possibilities from realities*
- *a way of helping people come to agreement*

Hallmarks of Science

1. *Seeks explanations for observed phenomena based on natural causes.*

2. *Progresses through the creation and testing of models that explain nature as simply as possible.*

3. *Makes testable predictions that would force us to revise or abandon model if predictions do not agree with observations.*

Strategy 2. Always Provide Context

Premise: We learn best when we integrate new ideas into mental "bins" (pre-existing or newly created).

- Note: This can be especially challenging for nonmajor courses in science, because students typically enter these courses without *any* pre-existing "bins" in which to organize new science knowledge.

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A key part of context is ***relevance***.

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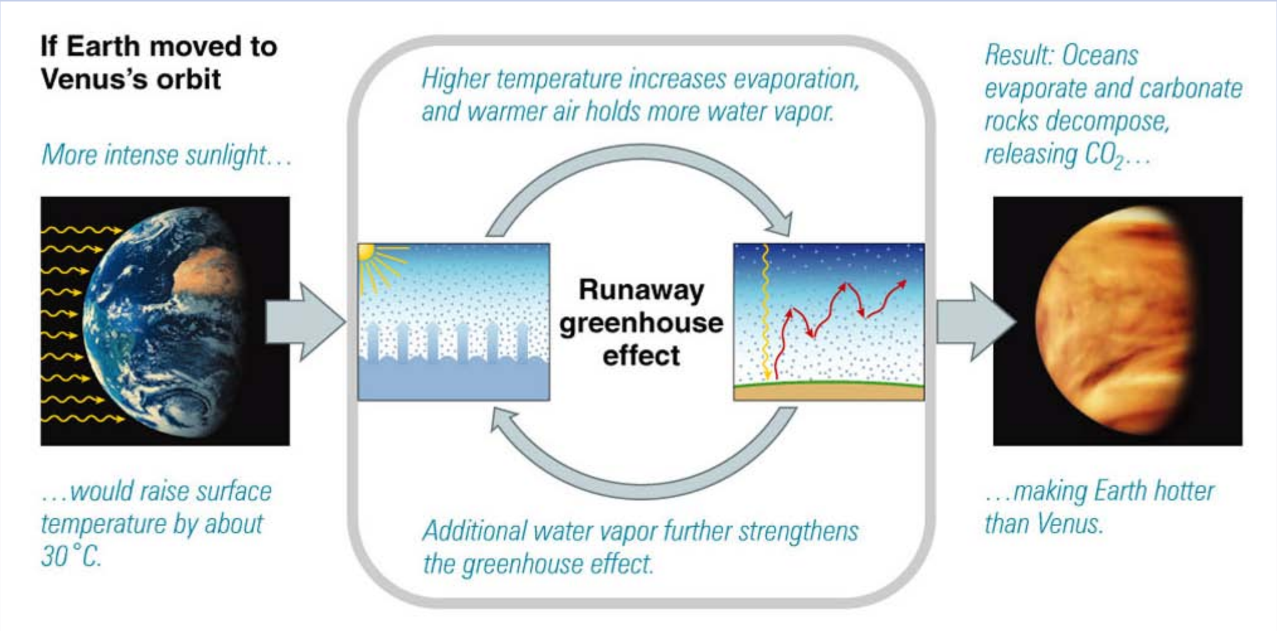
<u>Example:</u> Why should we care about Venus or Mars?



Strategy 3. Emphasize Conceptual Understanding

Premise: Facts are important, but it's too easy to fall into "stamp collecting" of facts at the expense of conceptual understanding.

Use concepts to guide selection of facts:

- relevance to big picture
- taught in context
- contribute to conceptual understanding

Strategy 4. Proceed from the Concrete to the Abstract.

Premise: Long known that this is the best way to learn.

Key approaches:

***context**-driven* vs. ***content**-driven* teaching

"bridges to the familiar"

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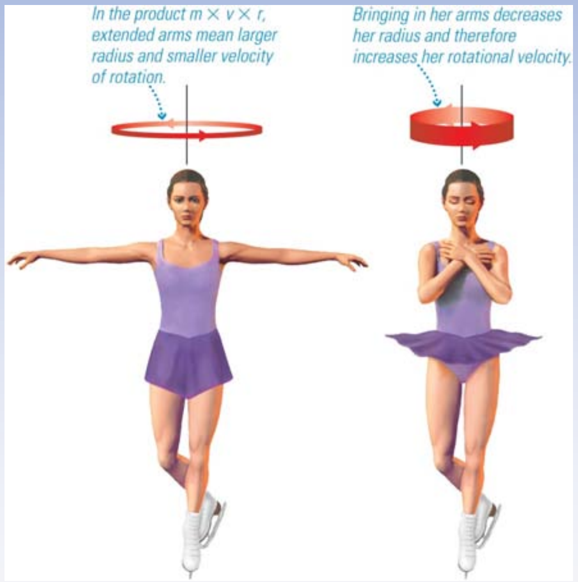
Example:



→

Strategy 5. Recognize and Address Student Misconceptions

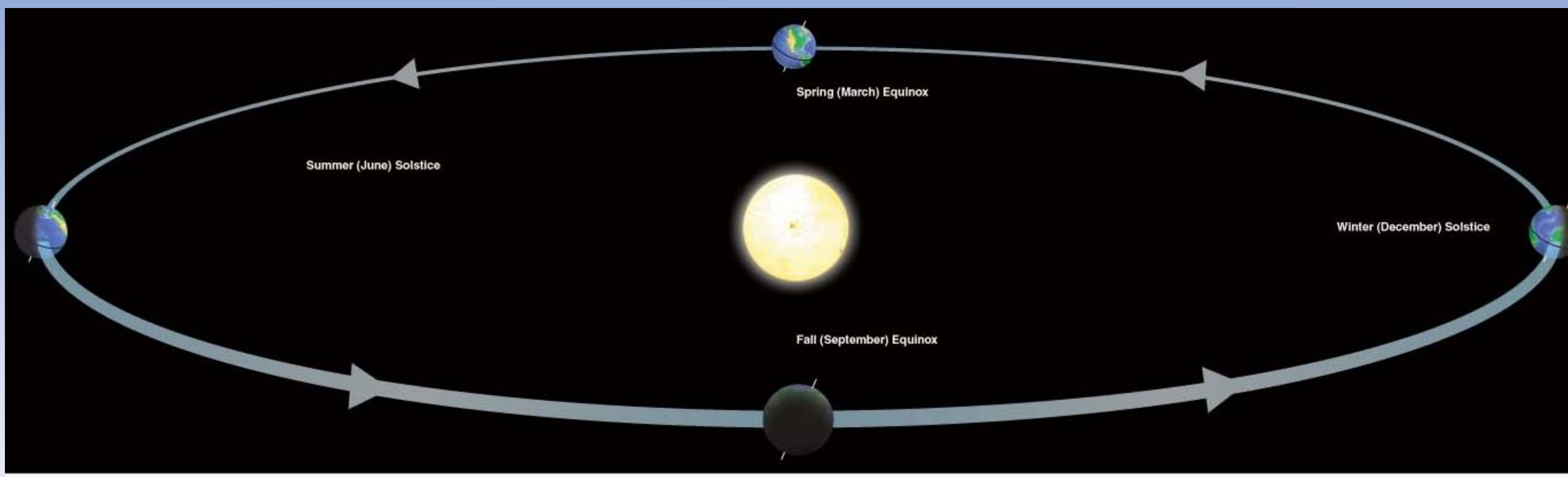
<u>Premise:</u> Students do not arrive as blank slates, and holding misconceptions that must be dispelled before they can learn the reality.

Identify misconceptions, then get students to recognize them for themselves. E.g.,

- dispel through experience – paper and rock
- "personal paradoxes"

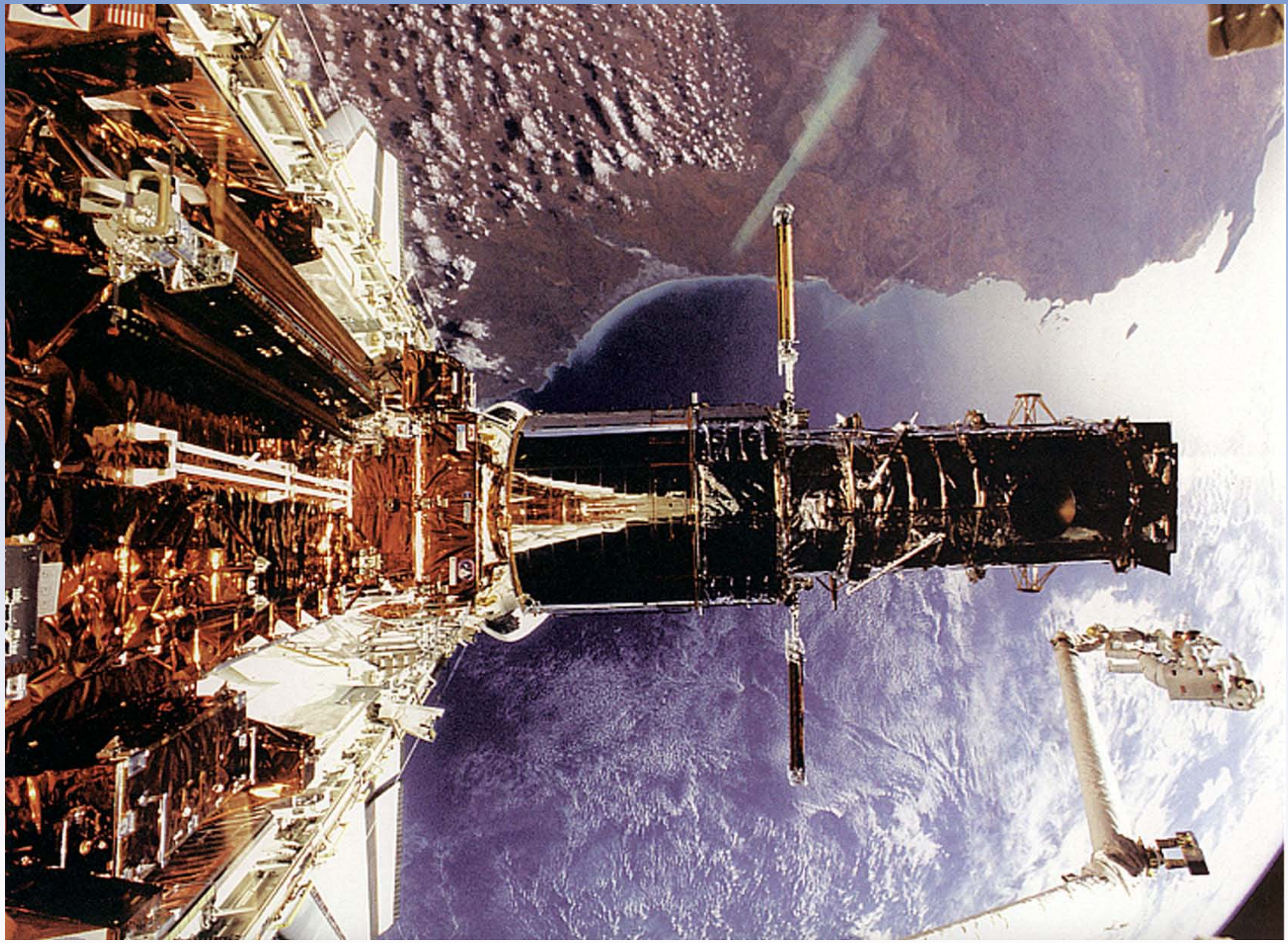
- seasons misconception :

→ "What season is it now in the southern hemisphere?"

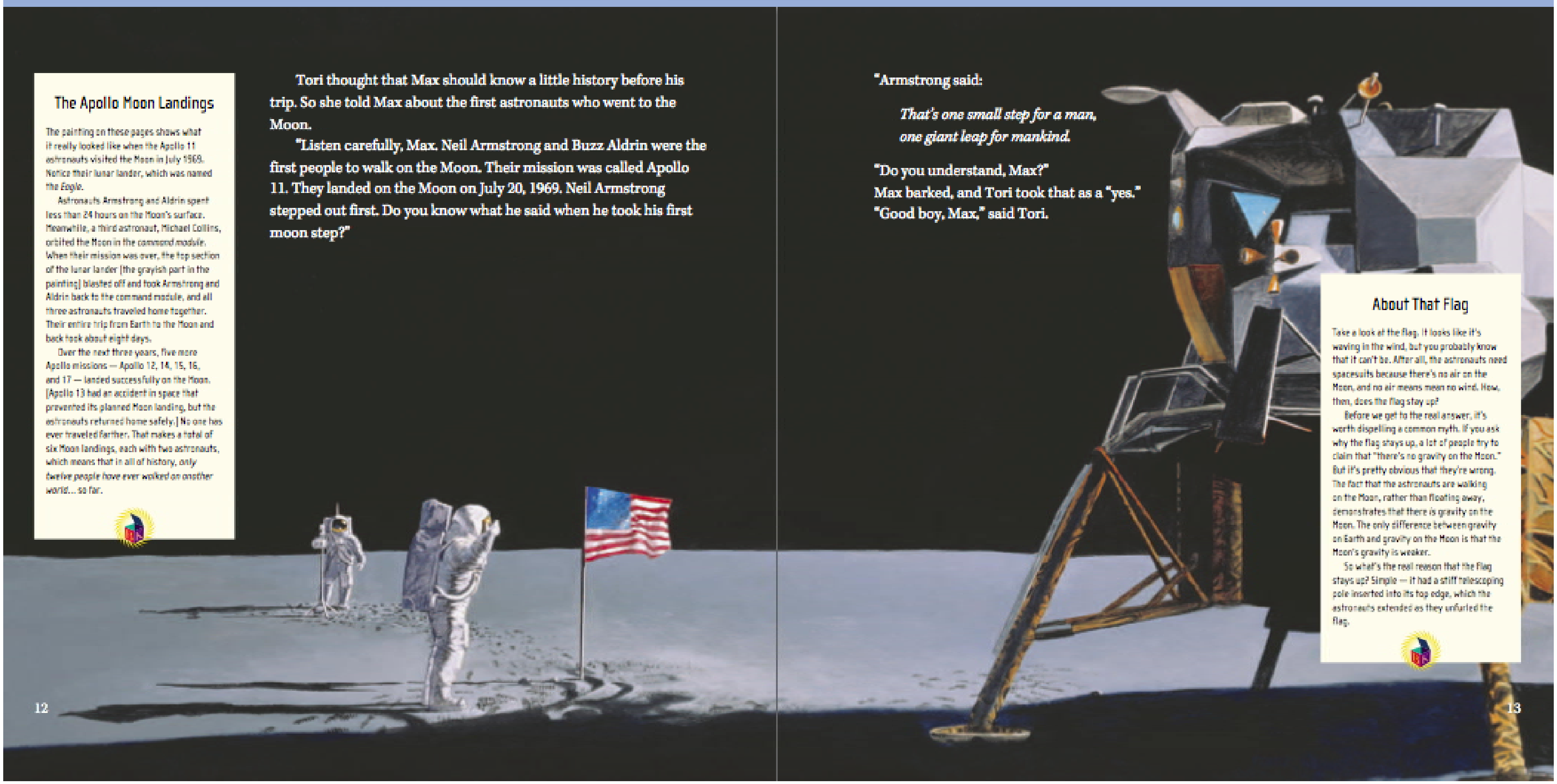


• misconception of “no gravity in space”:

→ Why does the moon orbit the Earth?



- Why does the flag stay up?



The Apollo Moon Landings

The painting on these pages shows what it really looked like when the Apollo 11 astronauts visited the Moon in July 1969. Notice their lunar lander, which was named the *Eagle*.

Astronauts Armstrong and Aldrin spent less than 24 hours on the Moon's surface. Meanwhile, a third astronaut, Michael Collins, orbited the Moon in the *command module*. When their mission was over, the top section of the lunar lander (the grayish part in the painting) blasted off and took Armstrong and Aldrin back to the command module, and all three astronauts traveled home together. Their entire trip from Earth to the Moon and back took about eight days.

Over the next three years, five more Apollo missions — Apollo 12, 14, 15, 16, and 17 — landed successfully on the Moon. (Apollo 13 had an accident in space that prevented its planned Moon landing, but the astronauts returned home safely.) No one has ever traveled farther. That makes a total of six Moon landings, each with two astronauts, which means that in all of history, *only twelve people have ever walked on another world... so far.*

Tori thought that Max should know a little history before his trip. So she told Max about the first astronauts who went to the Moon.

"Listen carefully, Max. Neil Armstrong and Buzz Aldrin were the first people to walk on the Moon. Their mission was called Apollo 11. They landed on the Moon on July 20, 1969. Neil Armstrong stepped out first. Do you know what he said when he took his first moon step?"

"Armstrong said:

That's one small step for a man,
one giant leap for mankind.

"Do you understand, Max?"
Max barked, and Tori took that as a "yes."
"Good boy, Max," said Tori.

About That Flag

Take a look at the flag. It looks like it's waving in the wind, but you probably know that it can't be. After all, the astronauts need spacesuits because there's no air on the Moon, and no air means mean no wind. How, then, does the flag stay up?

Before we get to the real answer, it's worth dispelling a common myth. If you ask why the flag stays up, a lot of people try to claim that "there's no gravity on the Moon." But it's pretty obvious that they're wrong. The fact that the astronauts are walking on the Moon, rather than floating away, demonstrates that there is gravity on the Moon. The only difference between gravity on Earth and gravity on the Moon is that the Moon's gravity is weaker.

So what's the real reason that the flag stays up? Simple — it had a stiff telescoping pole inserted into its top edge, which the astronauts extended as they unfurled the flag.

Strategy 6. Use Plain Language

Premise: The number of new terms in many introductory science books is larger than the number of words taught in many first courses in foreign language!

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For example: Do *you* know what these terms mean?

scarps on Mercury

lunar regolith

chondrites vs. achondrites

Strategy 6. Use Plain Language.

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Solutions:

scarps on Mercury = cliffs on Mercury

lunar regolith = powdery lunar soil

chondrites vs. achondrites =
primitive vs. processed meteorites

Strategy 6. Use Plain Language.

B— Simplify "necessary" jargon: Where jargon is unavoidable, seek acceptable alternative terms that may be more meaningful than traditional terms.

- hydrostatic equilibrium → gravitational equilibrium
- inertial reference frame → free-float frame
- Type I/II supernovae → white dwarf (Type Ia) or
massive star (Typea Ib, c, II)
supernovae
- Dwarfs…

Try my dwarf quiz:

1. What color is a brown dwarf?
   a. brown
   b. yellow
   c. magenta
   d. white

Try my dwarf quiz:

2. As a white dwarf cools over many millions of years, it changes:

a. white dwarf to red dwarf to brown dwarf to black dwarf.

b. white dwarf to red dwarf to black dwarf, but never becoming a brown dwarf.

c. white dwarf to red dwarf to dwarf planet.

d. white dwarf to black dwarf without passing through anything else in between.

Try my dwarf quiz:

5. What does a yellow dwarf turn into next, after it stops being a yellow dwarf?

a. Orange dwarf
b. Brown dwarf
c. White dwarf
d. Dwarf planet
e. Red Giant

Try my dwarf quiz:

11. In the event of SETI success, which type of dwarf is most likely to have sent the signal to us?

a. Red dwarf
b. Green dwarf
c. White dwarf
d. Brown Dwarf
e. Dwarf planet

Key point: *Professionals get comfortable with all this jargon, but it will drive our students nuts!*

Strategy 7. Challenge Your Students

Premise: Don’t dumb your teaching down; by and large, students will rise to meet your expectations, as long as you follow the other strategies and practice good teaching.

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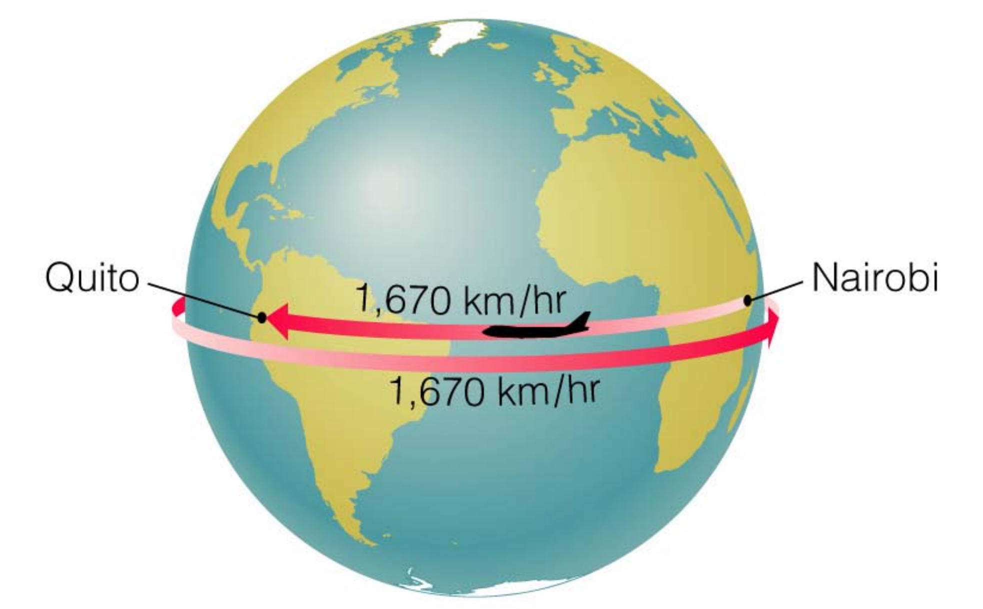
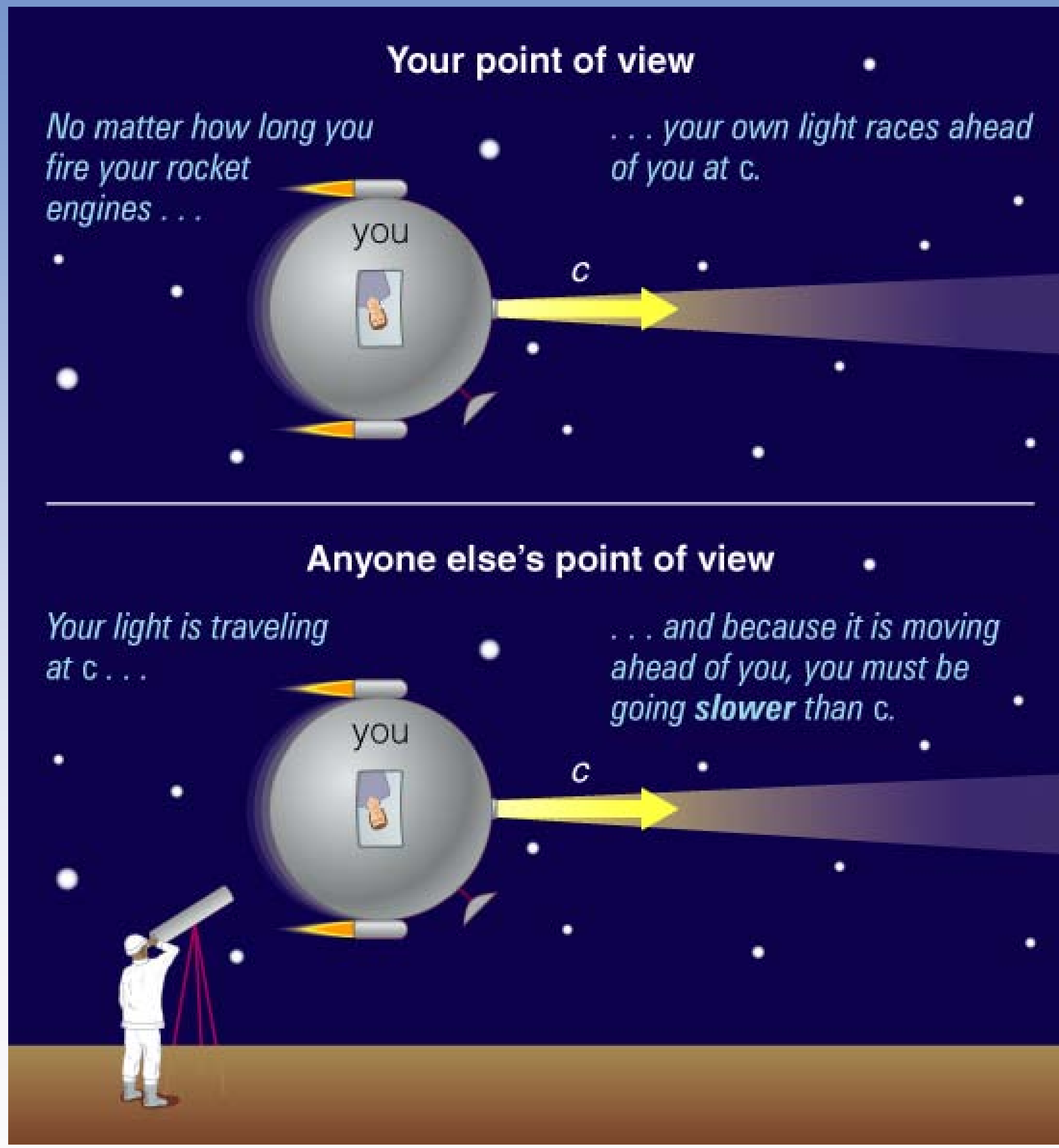
If a topic is important and interesting, find a way to present it. If you do it well, your students will find it just as interesting as you do.

My personal favorite example — Relativity

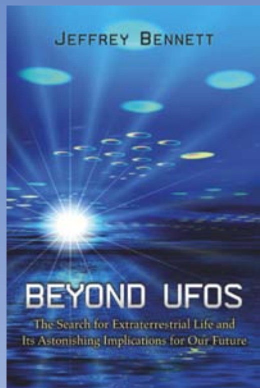
- Nearly everyone has heard of it — especially $E = mc^2$, prohibition on faster-than-light travel — and they want to know why.
- And it's really not that hard to explain, if you devote a bit of time to it.

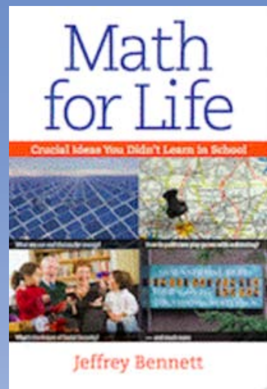


Why you can't go faster than a constant *c*:



For the general public:

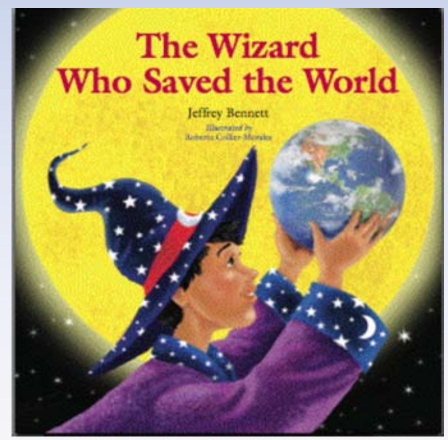




For children:

Textbooks (college):

As read from the Space Shuttle!



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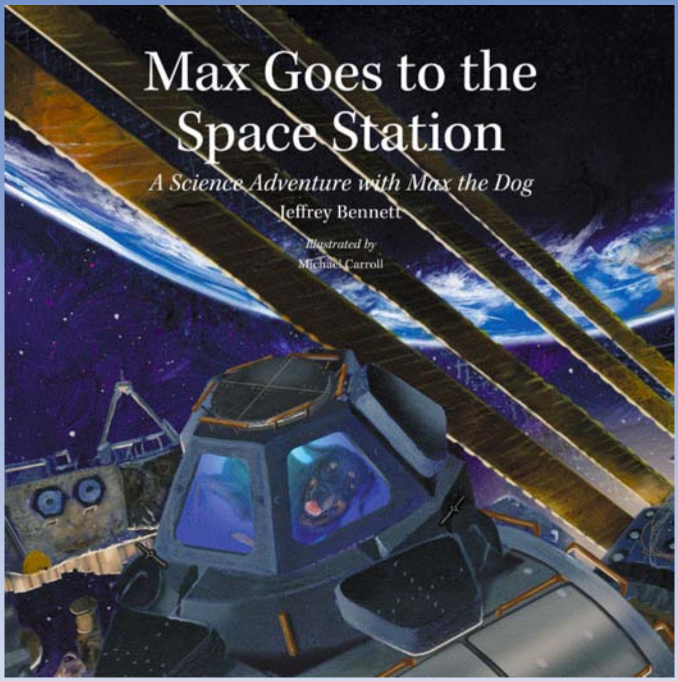
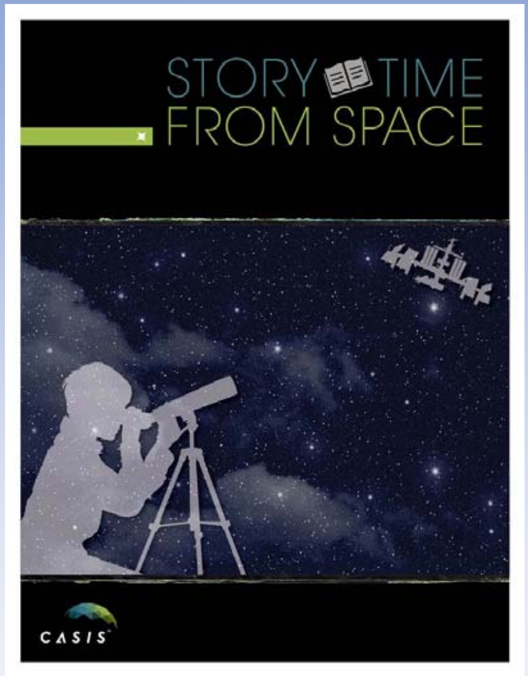
Don't miss…
The *Max Goes to the Moon* Planetarium show

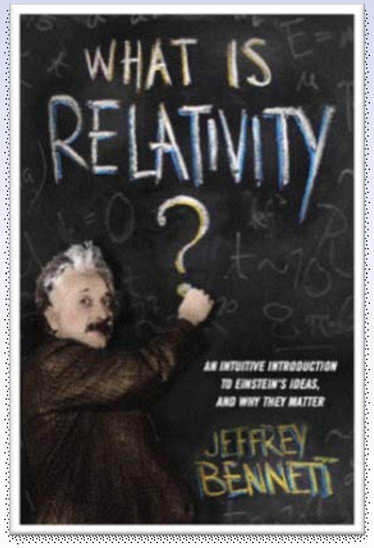
available to planetariums everywhere
www.bigkidscience.com/planetariumshow

Coming Soon…



Fall 2013:
-- Max Goes to the Space Station
-- "Story Time From Space"





early 2014

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