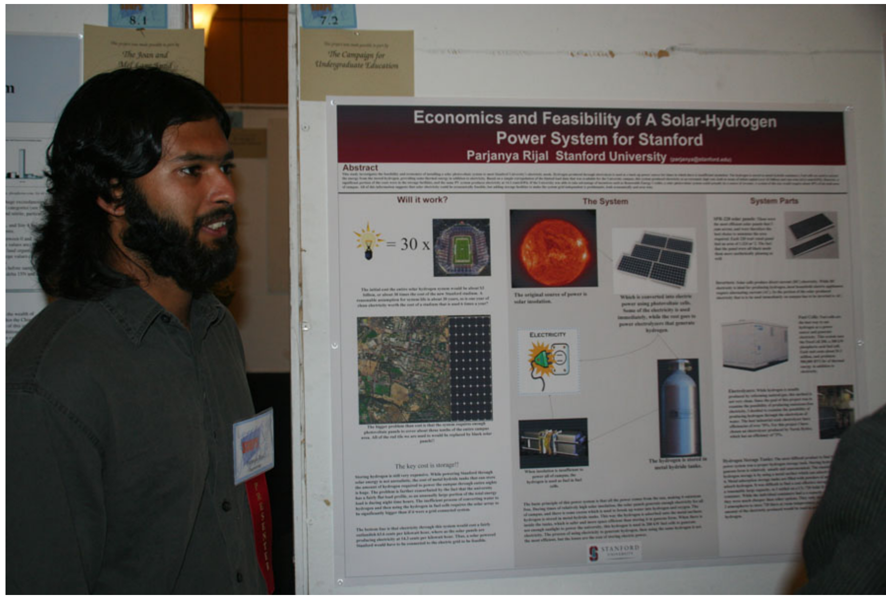
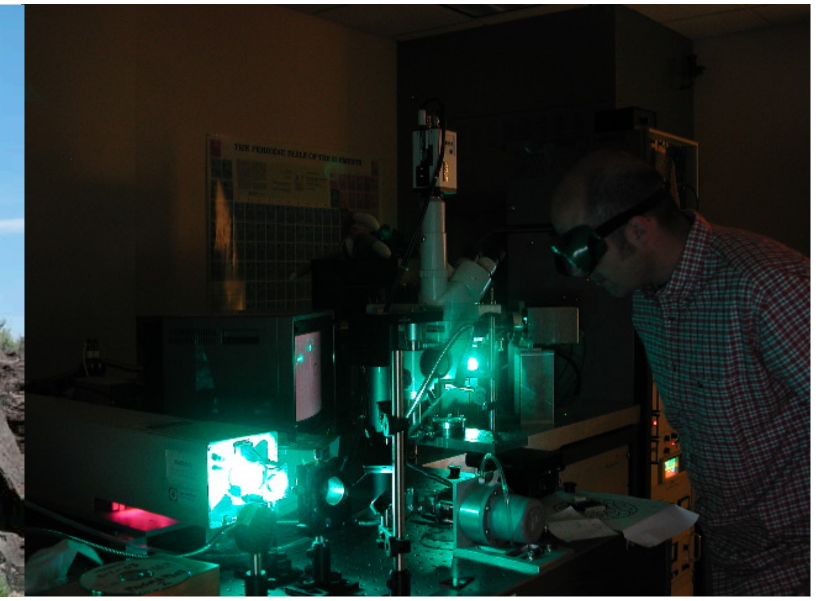
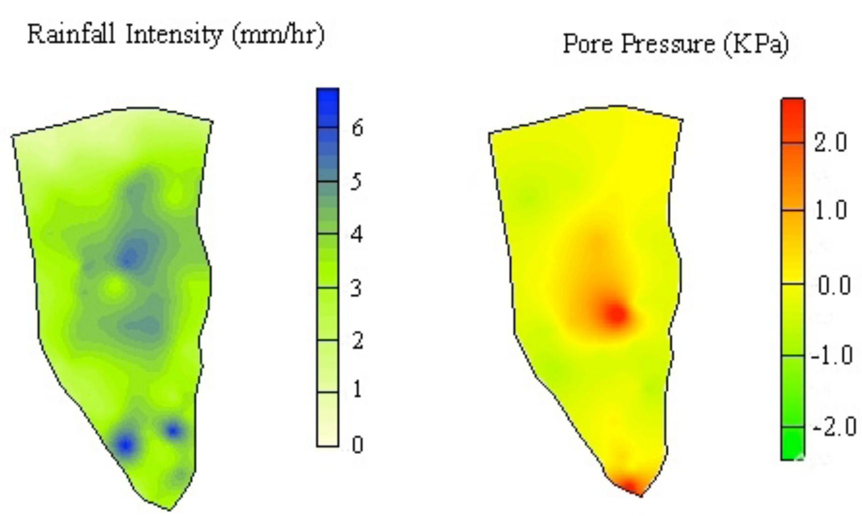


Teaching the Process of Science

Anne E. Egger
Stanford University *and* Visionlearning
14 December 2008



Introductory Geoscience

- Every year, 340,000 undergraduate students take college-level introductory geoscience courses in the United States
- 6000 students declare a major in the geosciences
  < 2% of students from introductory courses
- 2700 students graduate with a BS in the geosciences
  < 50% of declared cohort

Two audiences

Data from the American Geological Institute

Introductory Geoscience

- Our introductory courses are critical for recruiting majors into science disciplines
- These same courses may be the only science course that some students take
- Often have high enrollment
- Often considered the least desirable teaching assignment
- Traditionally overstuffed with content delivered in a lecture format

The role of introductory courses

...the primary aim of any undergraduate introductory science course—whether in biology, chemistry, physics, or earth sciences—should be to enable students to appreciate and participate in science as a special way of knowing about the world *Alberts, 2005*

In order to “appreciate and participate”...

Students need to understand

- **scientific content** - the theories, observations, ideas, and concepts that form a body of knowledge about the natural world
- **the process of science** - the means through which our conceptual and content knowledge was developed and continues to grow and change, and what makes it different from other ways of knowing
- **how science is used** - how individuals and societies benefit from and utilize the results of scientific investigation

The unique perspective of the geosciences

- Geologic time/deep time
- Spatial thinking, spatial analysis
- Complexity of the earth system
- Connection to landscape

Are we enabling our students to appreciate and participate in geoscience?

Well....

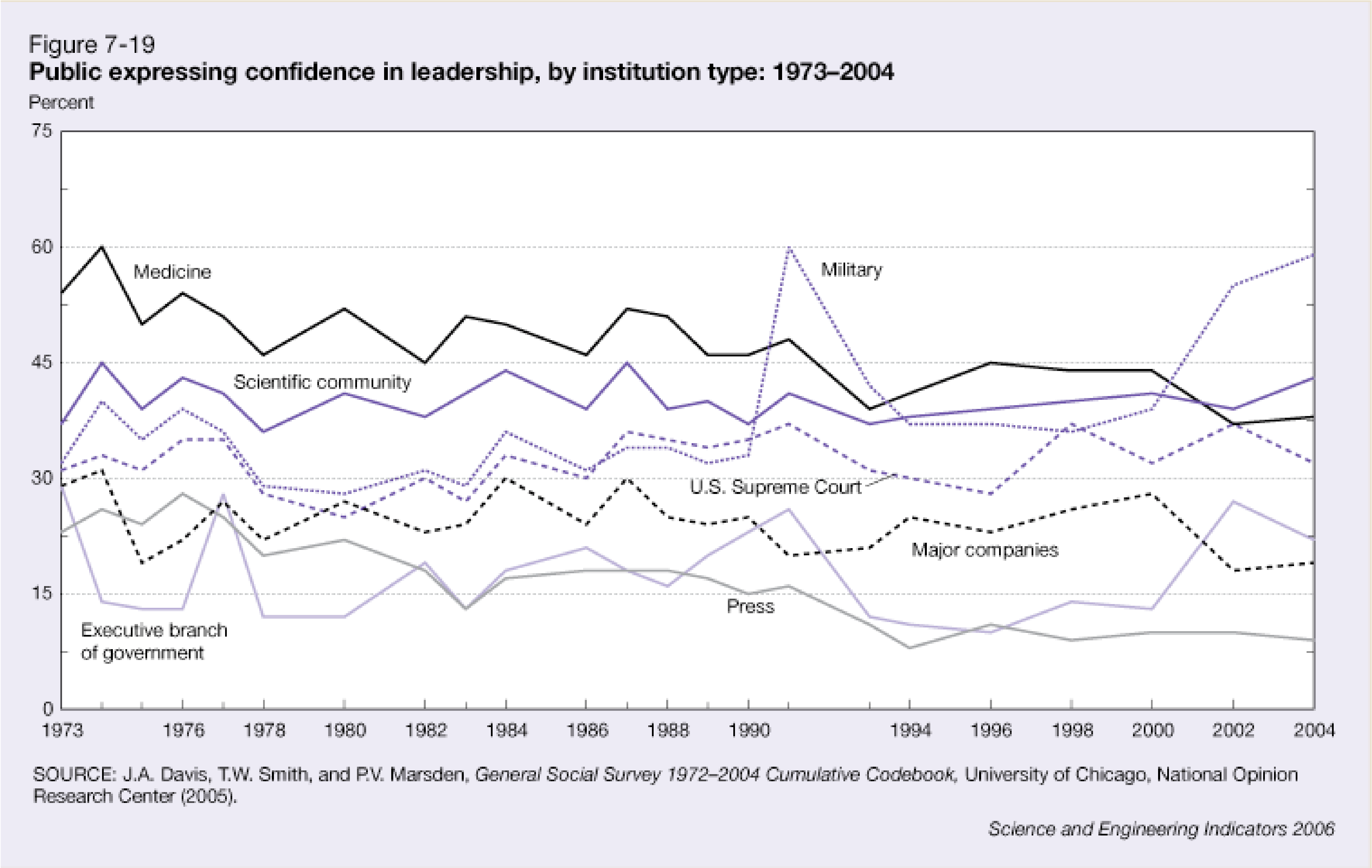
How do we measure up?

Results of a three-question NSF survey in 2001 and 2004:

- In 2001, only 43%of Americans and 37% of Europeans could explain an experiment (46% of Americans in 2004)
- 39% of Americans could describe the nature of scientific inquiry
- In 2004, only 23% of Americans surveyed could explain what it meant to study something scientifically
- As a result, “Americans are as likely to believe in flying saucers as in evolution...” Nicholas Kristoff, NYT Op-ed, Sunday, March 29, 2008

Data from NSB Science and Engineering Indicators 2006

Confidence in science



A lethal combination

- Don’t understand how science works
- High confidence in science, particularly medicine

What are we missing?

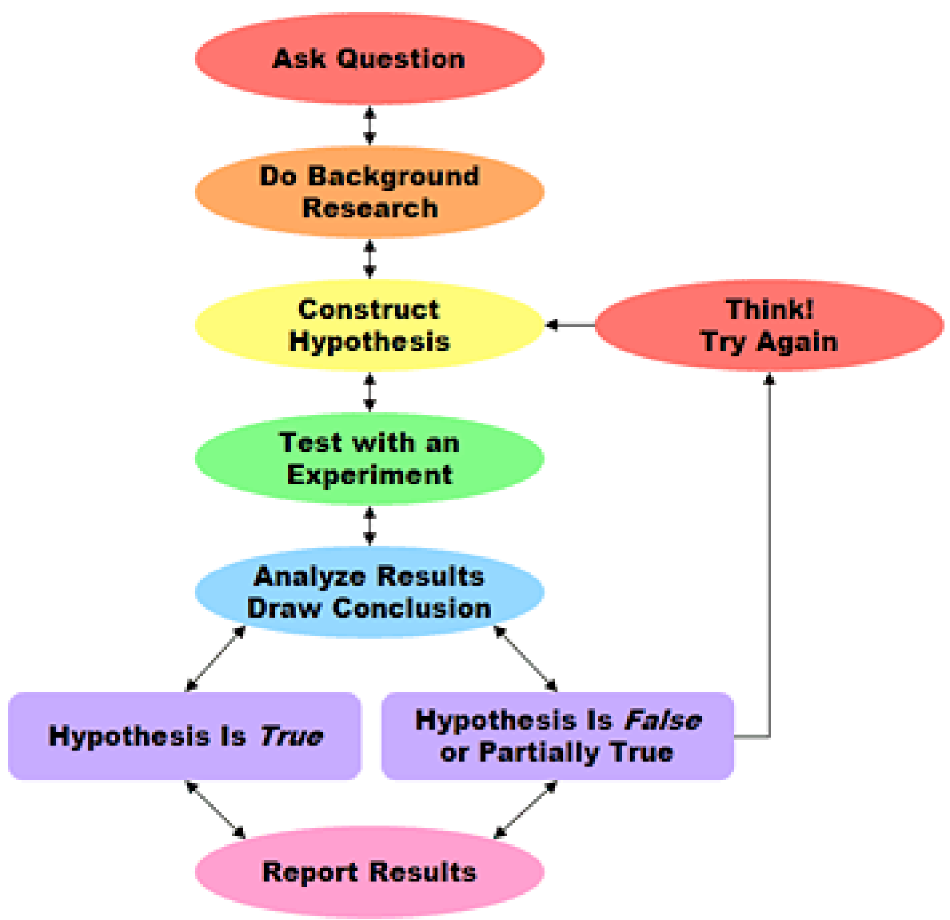
Students need to understand

- **scientific content** - the theories, observations, ideas, and concepts that form a body of knowledge about the natural world
- **the process of science** - the means through which our conceptual and content knowledge was developed and continues to grow and change, and what makes it different from other ways of knowing
- **how science is used** - how individuals and societies benefit from and utilize the results of scientific investigation

How do we teach the process of science?

Teaching the process:
Understanding misconceptions

- There is one scientific method, and it involves experimentation. *most K-12 textbooks and some college ones, too*



- And you must know the question first.

Teaching the process:
Understanding misconceptions

- There is one scientific method, and it involves experimentation. *most K-12 textbooks and some college ones, too*
- "Everything is science." *Moss et al., 2001 - Interviews of five US high school students in an environmental science class*
- "Technology is really good... so the computer can generate a good interpretation." *Ryder and Leach, 2000 - Paper survey of 731 science students across Europe + 19 interviews*
- Conceptual models are not an important part of data interpretation. *Ryder and Leach, 2000*
- Controversy resolves when experiments prove a theory right. *Ryder et al., 1999 - Interviews of 11 college students at Leeds involved in final year projects*
- Scientists may not work alone, but it is unclear how they interact. *Ryder et al., 1999*

Portrayals in the media

"But while Raymond-Whish's intimate acquaintance with cancer may **harm her credibility as a dispassionate scientist**, it may also propel her to help make startling discoveries where no one else has thought to look."

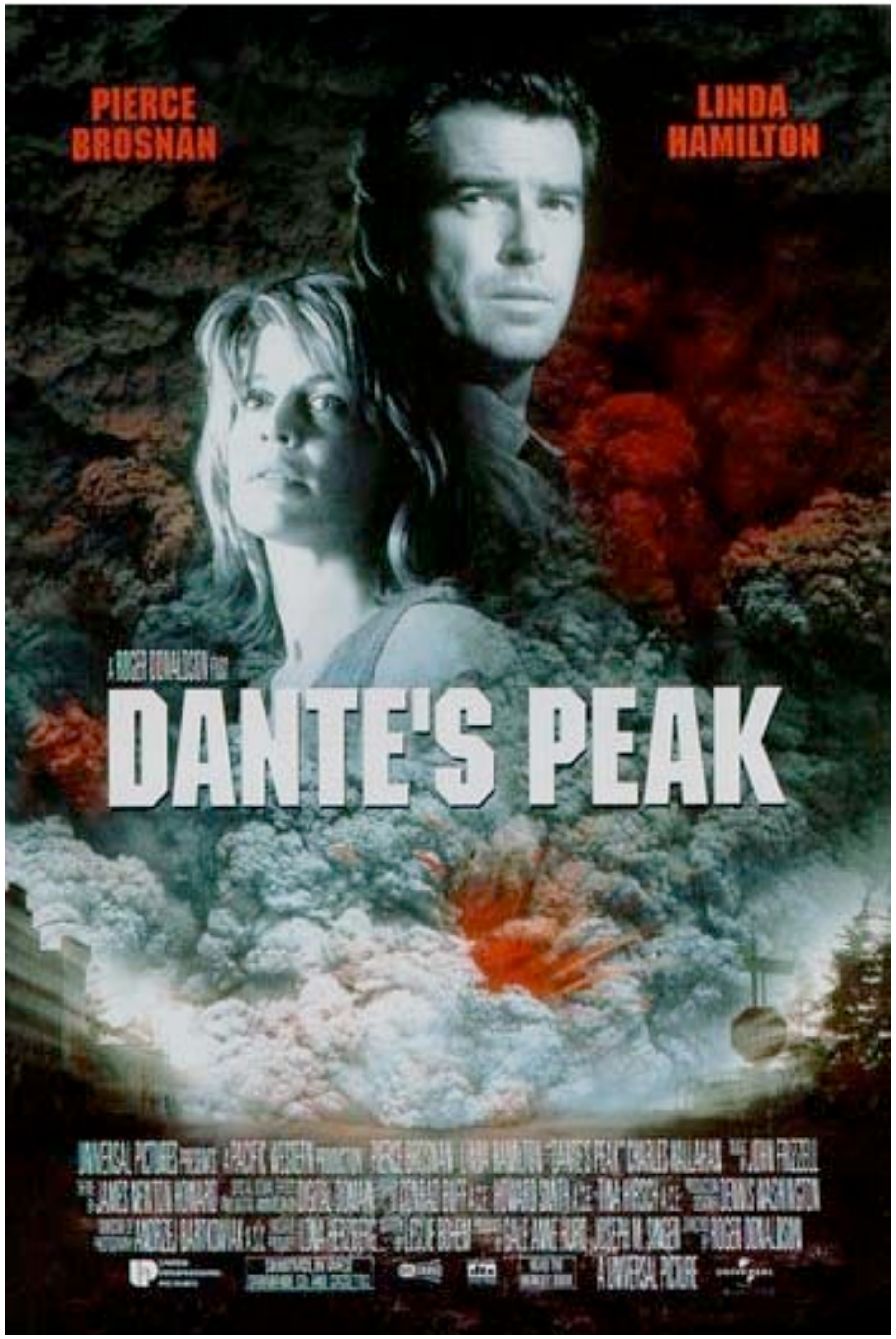
"On Cancer's Trail" Florence Williams, *High Country News*, May 26, 2008

"... Darwin... was hardly even a scientist in the sense that we understand the term - a highly trained specialist whose professional vocabulary is so arcane that **he or she can only talk to other scientists**."

"Who Was More Important, Lincoln or Darwin?" Malcolm Jones, *Newsweek*, July 14, 2008

Misconceptions about geoscien(ce/tists)

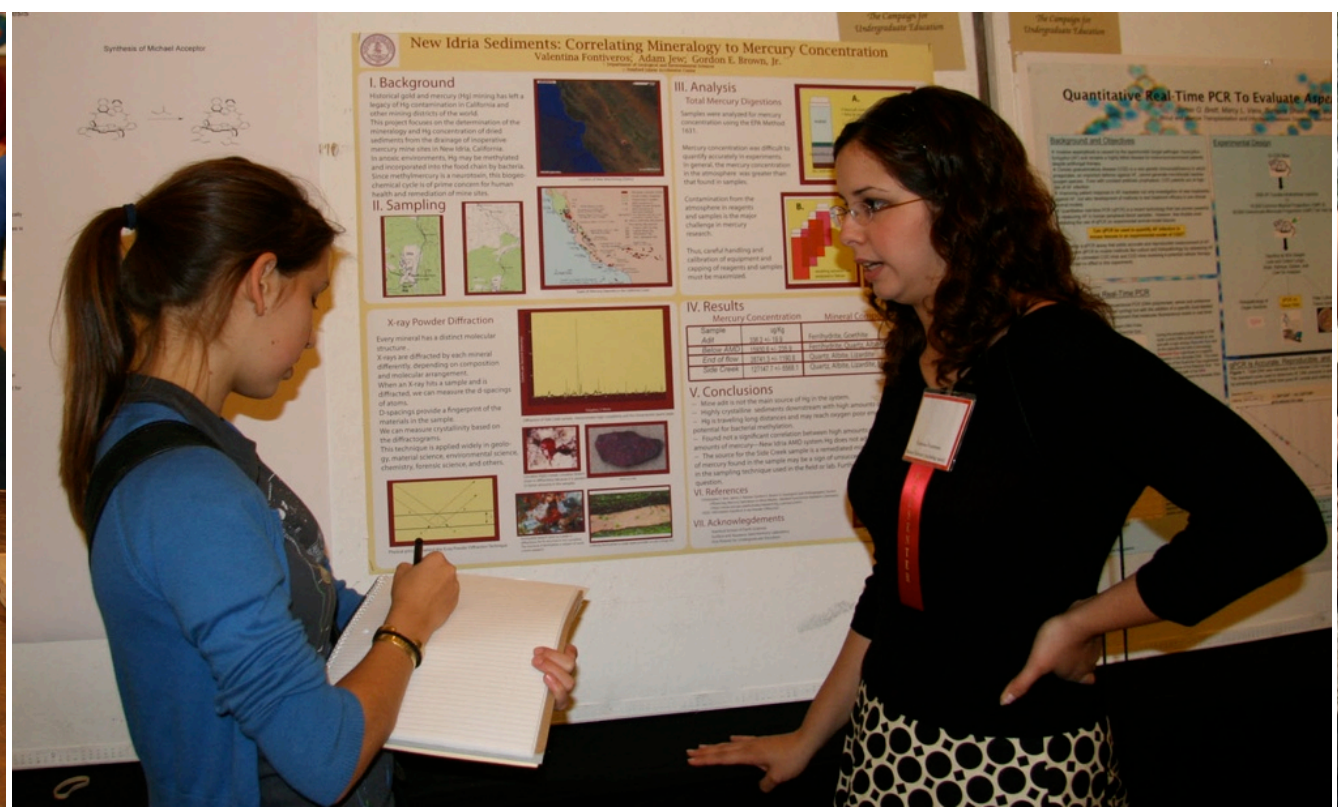
- Hypotheses developed about past events "can never be tested by experiment, and so they are unscientific" *(Gee, 1999)*
- Geology is not a laboratory science *(California)*
- Geologists dig (for fossils, archaeological sites, gold)
- [Enter favorite misconception here]
- Geologists look like Pierce Brosnan



What’s the solution?

Teach the process of geoscience: explicitly address misconceptions and provide new conceptions

- Discuss *methods* of geoscience rather than just *results*
- Involve students in the culture of research - even at the introductory level



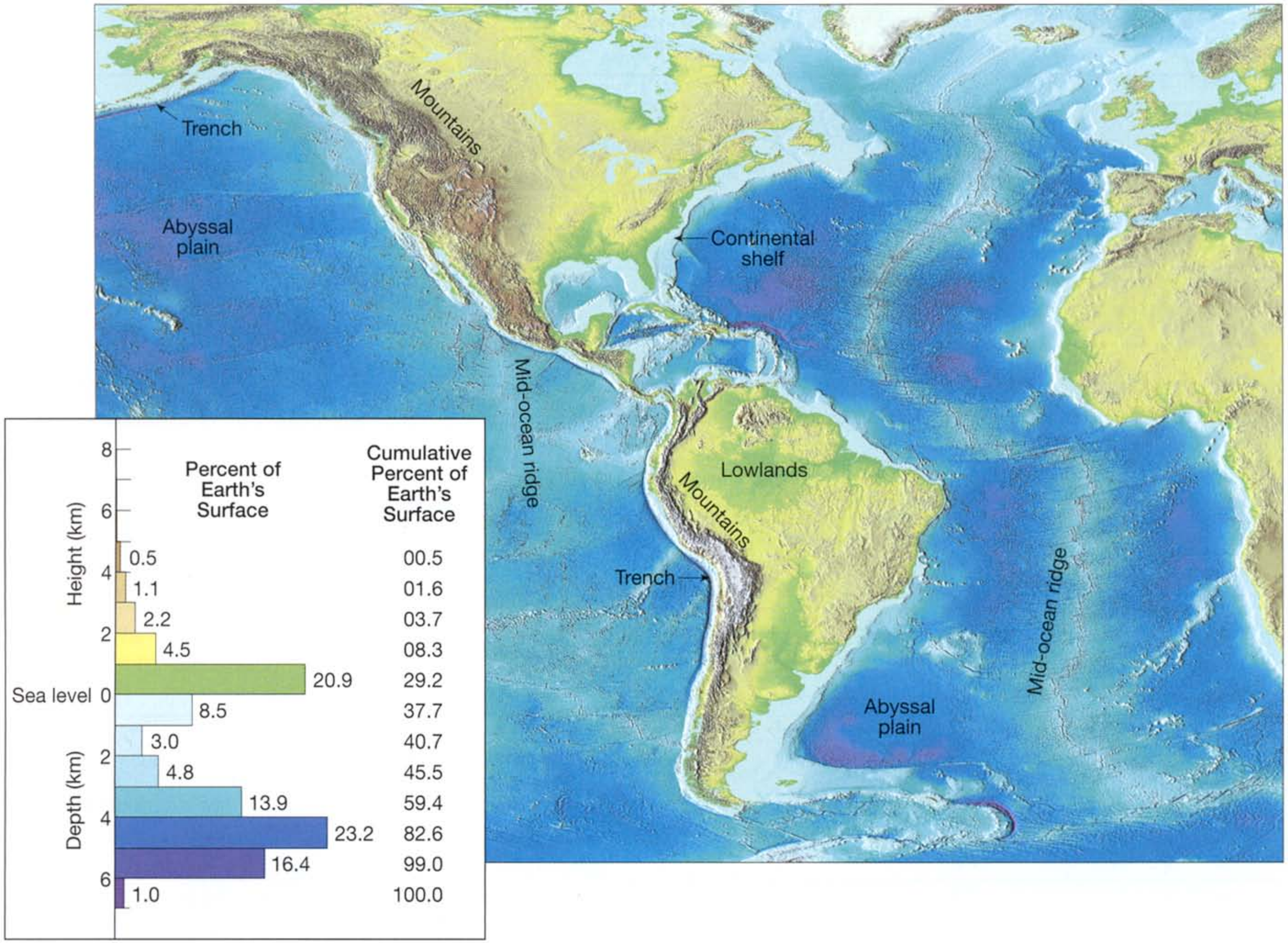
Teaching the process: *Active learning*

GES 1 Dynamic Earth

- Activity-based classes, integrated lecture-lab
- No textbook (but NOT no reading)
- Shift focus from content to tools and skills
- Shift focus from regurgitation to communication

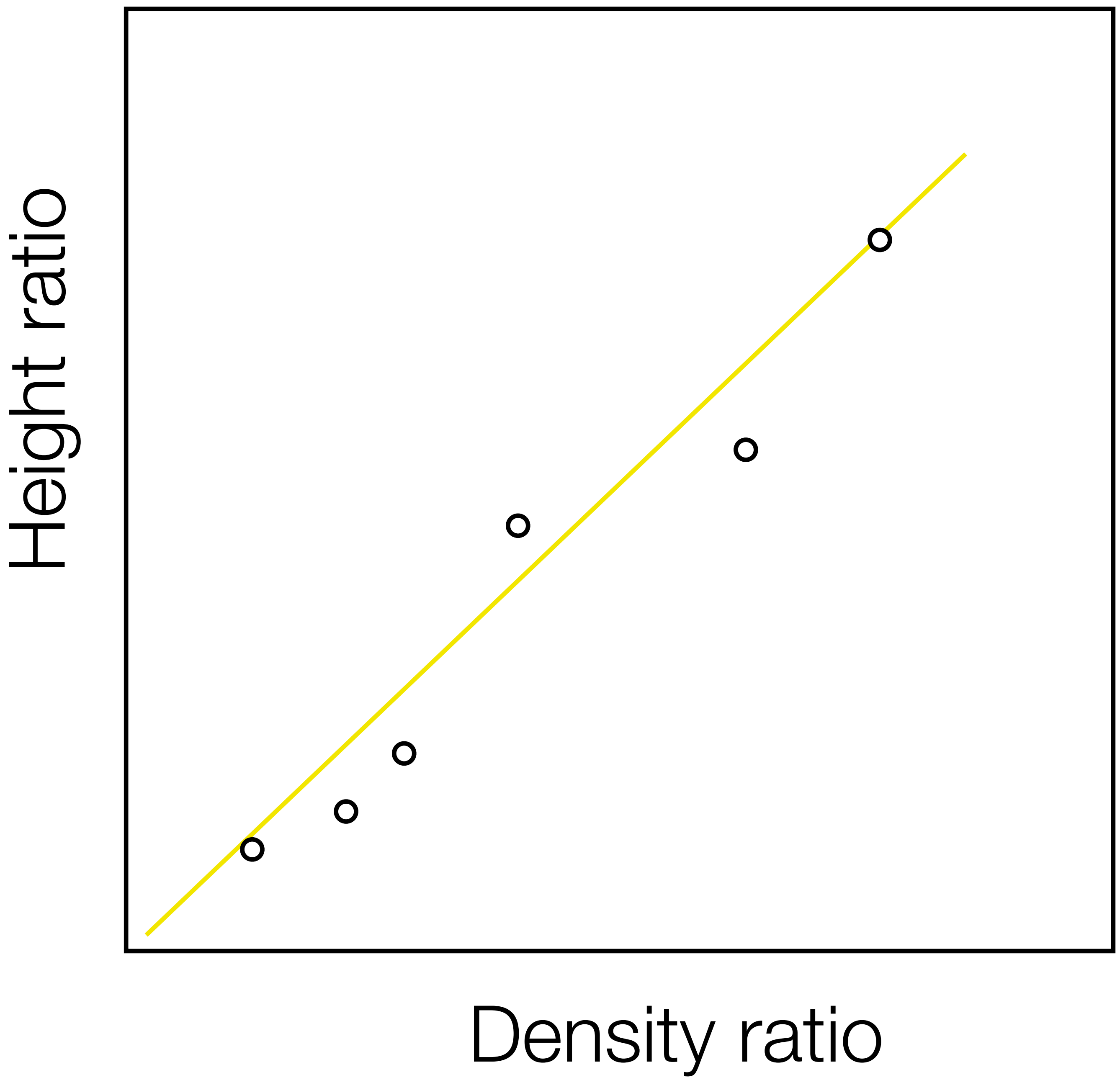
➡ *Less breadth, more depth*

Example activity:
Density, Isostasy, and Topography




Type of wood
Density
Mahogany
Redwood
Pine
Bubinga
Oak
WALNUT
pine
Oak

Wood block measurements

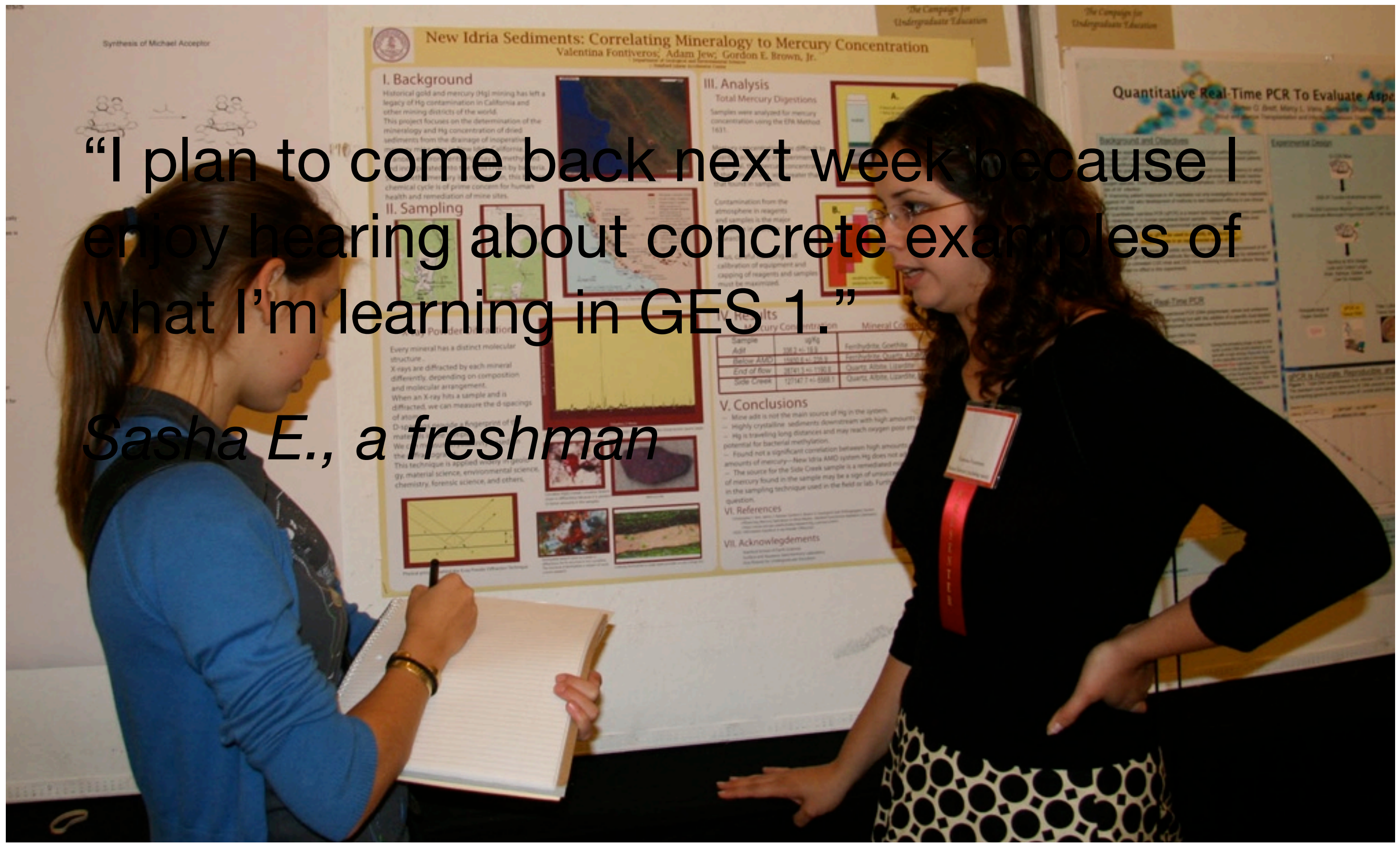


Follow-up questions

- Using your equation, calculate the thickness of the crust in the Andes, assuming they are made largely of granite and have an average elevation of 5 km above sea level.

- Based on what you now know about crustal thickness and isostasy, sketch what you would expect the crust to look like in an east-west cross-section across South America. Include approximate crustal thicknesses.

Teaching the process: *Exposure to research*

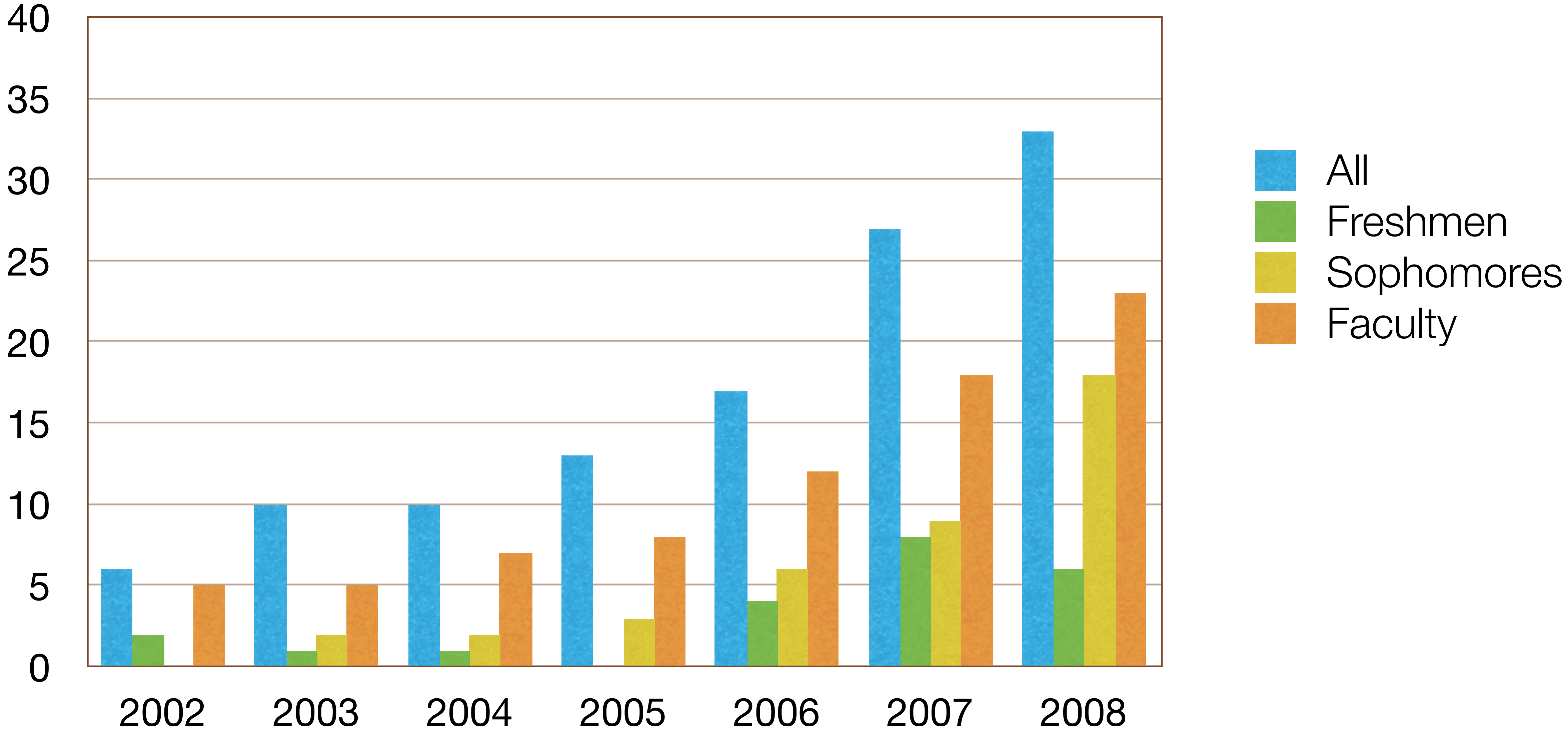


"I plan to come back next week because I enjoy hearing about concrete examples of what I'm learning in GES 1."

Sasha E., a freshman

- Integrated into introductory classes like Dynamic Earth: Required attendance at two research presentations
- Additional 1-unit class: GES 3 Current Topics in the Earth and Environmental Sciences

Teaching the process: *Exposure to research*



School of Earth Sciences Summer Undergraduate Research Program

Teaching the process: *People and stories*

- What do you do every day? (the mundane to the sublime)
- Why do you do what you do every day? (what inspired your pursuit of science)
- How do you know what we know? (how you collected the data on that graph)

Teaching the process: *New text resources*

Frontispiece from Sprat's 1667 *History of the Royal Society of London*

Visionlearning

Teaching the Process of Science

Free, online, modular readings that can be integrated with disciplinary content in a science class that include:

- Stories about modern research and historical development
- Examples from all disciplines
- Explicit acknowledgment of misconceptions

The Process of Science

Introduction: What is the Process of Science?

module I. The Process of Science

module II. Teaching the Process of Science (for faculty)

The Process of Science

module I. The Nature of Science

module II. Scientists and the Scientific Community

module III. Scientific Institutions and Societies

module IV. Science and Technology

module V. Science, Society, and Policy

module VI. Scientific Ethics

module VII. Ideas in Science: Theories, Hypotheses, and Laws

module VIII. Ideas in Science: Scientific Controversy

module IX. Ideas in Science: A Short History of Scientific Progress

The Process of Science

module X. The Practice of Science: An Introduction to Research Methods
module XI. Research Methods: Experimentation
module XII. Research Methods: Description
module XIII. Research Methods: Modeling
module XIV. Research Methods: Comparison
module XV. Data: Analysis and Interpretation
module XVI. Data: Statistics
module XVII. Data: Using Graphs and Visual Data
module XVIII. Data: Uncertainty, Error, and Confidence
module XIX. Scientific Writing: Understanding Journal Articles
module XX. Scientific Writing: Peer Review
module XXI. Scientific Writing: Literature

Conclusion: Science and You

module XXII. Science and You

Visionlearning®

My Profile | Log Out [Search]

student is currently logged in.

Library **MyClassroom** **About Us** **Help**

Library

Our Library is an award-winning collection of peer-reviewed learning modules written by professional educators and scientists. These modules provide text, interactive animations, glossary definitions, current news and research, scientist biographies and practice exercises to provide a rich and complete learning environment. Modules in our Library can be sorted by subject or science standard and can be customized in our MyClassroom.

Our library is also available in Spanish.

Click on a category to see more detailed descriptions of the modules. Click on a module title to go directly to a module.

Astronomy

- The Universe: Beginnings

Biology

- Adaptation: The Case of Penguins
- Cells: Discovery and Basic Structure
- Charles Darwin I: The Origin of Species
- Charles Darwin II: Natural Selection
- Charles Darwin III: Descent with modification
- DNA I: The Genetic Material
- Genetics I: Mendel's Laws of Inheritance
- Genetics II: Mendel's Scientific Legacy and Analysis of Multiple Genetic Traits
- Nucleic Acids: DNA and RNA
- Taxonomy I: What's in a name?
- Taxonomy II: Nomenclature: Ruling names of giants

Chemistry

- Acids and Bases: An Introduction
- Atomic Theory I: The Early Days
- Atomic Theory II: Ions, Isotopes and Electron Shells

Library Biblioteca en español

- ▶ Astronomy
- ▶ Biology
- ▶ Chemistry
- ▶ Earth Science
- ▶ General Science
- ▶ Physics
- ▼ Process of Science
  - Data: Analysis and Interpretation
  - Data: Statistics
  - Data: Uncertainty, Error, and Confidence
  - Data: Using Graphs and Visual Data
  - Research Methods: Comparison
  - Research Methods: Description
  - Research Methods: Experimentation
  - Research Methods: Modeling
  - Scientific Writing I
  - The Practice of Science
- ▶ Toxicology & Pharmacology
- ▶ Trigonometry
- ▶ Interactive Animations

http://beta.visionlearning.com

Visionlearning®

My Profile | Log Out Search

annegger is currently logged in.

Library **MyClassroom** **About Us** **Help**

Library > Process of Science > Research Methods: Modeling

Module | Questions & Quizzes | Links

Research Methods: Modeling

by Anne E. Egger, Anthony Carpi

Learning Objectives ▼ hide

- Modeling involves developing physical, conceptual, or computer-based representations of systems.
- Scientists build models to replicate systems in the real world through simplification, to perform an experiment that cannot be done in the real world, or to assemble several known ideas into a coherent whole to build and test hypotheses.
- Computer modeling is a relatively new scientific research method, but it is based on the same principles as physical and conceptual modeling.

LEGO® bricks have been a staple of the toy world since they were first manufactured in Denmark in 1953. The interlocking plastic bricks can be assembled into an endless variety of objects (see Figure 1). Some kids (and even many adults) are interested in building the perfect model – finding the bricks of the right color, shape, and size, and assembling them into a replica of a familiar object in the real world, like a castle, the space shuttle, or London Bridge. Others focus on using the object they build – moving LEGO knights in and out of the castle shown in Figure 1, for example, or enacting a space shuttle mission to Mars. Still others may have no particular end product in mind when they start snapping bricks together and just want to see what they can do with the pieces they have.

Visionlearning Resources

Glossary

Quotes

Dr. Richardson said that the atmosphere resembled London for in both there were always far more things going on than anyone could properly attend to.

-George C. Simpson, 1929

http://beta.visionlearning.com

Making the change

"As mediators of the cultures of science, science teachers at all levels in the educational system need to **make explicit to themselves** the images of science communicated through existing ... activities and those additional images they wish to incorporate..." (Ryder et al., 1999)

Small changes

Big changes

Feedback into the scientific enterprise

If faculty at universities “marshal their collective will to reform science education, the impact could be far-reaching. We will send non-science majors into society knowing how to ask and answer scientific questions and be capable of confronting issues that require analytical and scientific thinking. Our introductory courses will encourage more students to become scientists [and to think like scientists] ... Students will see the allure of science and feel the thrill of discovery, and a greater diversity of intellects will be attracted to careers in science. **The benefits will be an invigorated research enterprise fueled by a scientifically literate society.”**

Handelsman et al., Scientific Teaching, 2001