Science Literacy

Prof. Aprahamian
Science: A Way of Knowing

How do you know what you know?
GREAT IDEA

Science is a way of asking and answering questions about the natural universe.

PHYSICS
What forces exist in the universe? (Ch. 8)

CHEMISTRY
How can we combine atoms to form new materials? (Ch. 11)

ENVIRONMENT
Do human activities affect Earth's global climate? (Ch. 19)

GEOLOGY
What dynamic processes occur in Earth's deep interior? (Ch. 17)

HEALTH & SAFETY
What causes cancer? (Ch. 24)

ASTRONOMY
What will be the ultimate fate of the universe? (Ch. 15)

TECHNOLOGY
How can we design more efficient power plants? (Ch. 4)

BIOLOGY
How do complex organisms develop from a single cell? (Ch. 25)

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Scientists discover laws that describe how nature works by performing reproducible observations and measurements. Every idea in science must be subject to this kind of testing.

If an idea cannot be tested in a manner that yields reproducible results, even if that idea is correct, then it simply isn't a part of science.

But the methods of science cannot answer other equally valid questions. No physical or chemical test will tell us whether the painting is beautiful or how we are to respond to it. These questions are simply outside the realm of science.
Identifying Patterns and Regularities

• Measurement - better description
• Data - table or graph
• Patterns emerge
• Describe:
  – In words
  – In equation form
  – In symbols
The Scientific Method

Scientific method

Identifying patterns

Observations, Experiments, Data

Preconceptions

Hypothesis

Prediction
The Scientific Method in Operation

- **Cycle**
  - Not rigid
- **Believe results**
  - No preconceptions
- **No true starting place**
- **Results must be reproducible**
- **Cycle is continuous**
Prediction and Testing

• Predictions
  – Hypothesis, Theory, Law
  – Must be quantitatively testable

• Testing
  – Do not prove or disprove
  – Define range of validity

• Every law and theory of nature is subject to change, based on new observations
Facts, Hypotheses, Laws, and Theories

• Fact
  – Confirmed observation

• Hypothesis
  – Educated guess

• Law
  – Description of nature

• Theory
  – Well-substantiated description
The scientific method is not the only way to answer questions that matter in our lives. Science provides us with a powerful way of tackling questions about the physical world—how it works and how we can shape it to our needs. But many questions lie beyond the scope of science and scientific methods.

Some of these questions are deeply philosophical:
What is the meaning of life?
Why does the world hold so much suffering?
Is there a God?

Other important personal questions also lie outside of science:
What career should I choose?
Whom should I marry?
Should I have children?

Scientific information might influence some of our personal choices, but we cannot answer these questions fully by the cycle of observation, hypothesis, and testing. For answers, we turn instead to religion, philosophy, and the arts.
Theories and the Theory of Evolution

Discussion Question 1

1. According to Bill Nye, your textbook, and all other scientific sources in the world, what is a theory?
   
a. something that happens in nature
b. a conjecture based on past observations
c. a widely tested and accepted set of ideas
d. an interesting idea, but not one that can be tested
Theories and the Theory of Evolution

Discussion Question 2

2. Bill Nye says what any scientist would say, namely, that evolution is the basis of biology. When a non-scientist says that evolution is “just a theory,” what is wrong with that?

a. The speaker does not understand what a scientific theory is all about.

b. The speaker is being cautious as any scientist would.

c. The speaker really means that evolution is a fact.

d. The speaker is confusing an untestable hypothesis with a theory.
Theories and the Theory of Evolution

Discussion Question 3

3. What is the problem, from a scientific point of view, of including non-testable ideas in a science classroom?

a. Students might get the wrong idea about religion.

b. Students would think - wrongly - that un-testable ideas are a part of science.

c. Scientists want everyone to think like them.

d. Scientists themselves do not have a clear view of what non-testable ideas are.
Science in the Making

• Dimitri Mendeleev and the Periodic Table
# Periodic Table

<table>
<thead>
<tr>
<th>Periods</th>
<th>Alkali Metals</th>
<th>Alkaline Earth Metals</th>
<th>Halogens</th>
<th>Noble or Inert Gases</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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<td>1 H</td>
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<tr>
<td>7</td>
<td>Y</td>
<td>La</td>
<td>Br</td>
<td></td>
</tr>
</tbody>
</table>

**Atomic Number and Atomic Mass**

- Periodic Table elements are arranged by atomic number and atomic mass.
- Elements are classified into categories: metals, metalloids, and nonmetals.

**Periods**

- Periods represent horizontal rows of elements.
- Periods 1 to 7 are shown.

**Groups**

- Groups are vertical columns of elements with similar chemical properties.
- Groups 1A to 18A are identified.

**Specific Elements**

- Examples: H (Hydrogen), He (Helium), Na (Sodium), Mg (Magnesium), Al (Aluminum), Si (Silicon), Ge (Germanium), As (Arsenic), Sb (Antimony), Bi (Bismuth), I (Iodine), Xe (Xenon), At (Astatine), and Rn (Radon).
Other Ways of Knowing
Different Kinds of Questions

- Cannot always use scientific method
- Art
  - Use to address age of painting
  - Not for beauty, etc.
- Religion
  - No conflict between science and religion
  - Faith vs. experiment
Pseudoscience

• Pseudoscience
  – Belief, dogma
  – Ideas not testable

• Evaluation of a claim
  1. Are the ‘facts’ true as stated?
  2. Is there an alternative explanation?
  3. Is the claim falsifiable?
  4. Have claims been tested?
  5. Do claims require unreasonable changes in accepted ideas?
Fortune Telling
Astrology
Let's try a few examples

• Can we distinguish science questions from others?

• What sorts of things we can get a true/false answer to by science?

• Who are the scientists?
The Organization of Science
First a bit of history for the US: Evolution of a culture of research and science investment....

Vannevar Bush 1945 Report to President Truman....
"Science - The Endless Frontier"

1. **Government must be the principal source of funding** for basic science

2. Basic science should be located primarily in universities that combine research with the education of next generation of scientists, engineers, and business leaders

3. **Government should allocate funding across broad categories of science**, but The decision to allocate funds to particular projects should be made by **Independent scientific experts**.

Federal support of basic research drove universities and their research enterprises

- NSF
- DOE
- NIH

Universities and Federal Research agencies led to some of the most profound World discoveries of the 20th century.....!

- www
- Gps
- Cellphones
- Computers
US history of supporting research in a critical need area goes back to Partnership of Federal government with universities …

Critical need a century ago was agriculture, mechanics, and home economics

Land grant colleges….1862…Morrill Act

Allowed each state to establish a land grant college/university in these crucial areas. Faculty….had to do research in areas of need and to share their results with the surrounding Communities....

Explosion of farming technologies, equipment, food industry

Right now…our great challenges are Climate Change, Energy, Water, Population

Future….We don’t know what challenges will come…..
Research today is done in **Universities**

**National laboratories**

**Industry**

(predictable cash flows and regulated monopolies are now gone)

*But.....industry has changed since you were born...in the 1990's*

Decline of research by industry and specialized research laboratories

*Companies today....take the very short term view to profits...*

So.....we have **universities, national laboratories and the federal government**.

We need.....**new policies to address the changing times.....**

New policies for universities
New policies for industries
New policies for the federal government
Divisions of Science

• Disciplines
  – Historical
  – Modern

• Approach
  – Field researcher
  – Experimentalists
  – Theorists
The Branches of Science

- Physics
  - Fundamental aspects of nature

- Chemistry
  - Atoms in combination

- Biology
  - Living systems

- Astronomy
  - Objects in space

- Geology
  - Earth
The Web of Knowledge

• Center
  – Laws of nature
  – Apply to all areas

• Areas Interconnected
  – All branches integrated
The Interconnected Web of Scientific Knowledge
Basic and Applied Research and Technology

• **Basic Research**
  – Expand knowledge

• **Applied Research**
  – Direct application
    • Technology
    • Conservation
    • Medicine
Funding for Science

• **US Government**
  – $130 billion
  – NSF, NIH, DOE, DOD, EPA, NASA, NOAA

• **Apply for funds**
  – Grant proposal
    • Ranked by independent scientists
    • Highly competitive
Major Research Laboratories nearby.....

Argonne National Laboratory near Chicago

Fermi Laboratory near Chicago

Others???? Nuclear Science Laboratory here at Notre Dame
  Radiation Laboratory at Notre Dame
Total R&D by Agency, FY 2012

budget authority in billions of dollars

- DOD, $77.8
- HHS (NIH), $32.4
- DOE, $13.0
- NASA, $9.8
- NSF, $6.1
- USDA, $2.4
- Commerce, $1.7
- All Other, $6.0

Total R&D = $149.1 billion

Source: OMB R&D data, agency budget justifications, and other agency documents. R&D includes conduct of R&D and R&D facilities. © 2011 AAAS
International R&D Investment

- The United States leads the world in R&D investment
  - $398b PPP, 34.6% of world R&D investment
- But, others are quickly increasing their investment
  - Over 1997 - 2007,
    - South Korea, +0.99% of GDP to 3.47%
    - China, +0.85% of GDP to 1.49%
    - Taiwan, +0.81% of GDP to 2.63%
    - Japan, +0.57% of GDP to 3.44%
    - United States, +0.10% of GDP to 2.68%
- President Obama set goal of 3.0% of GDP investment in R&D
Total World R&D, 2008
in billions of PPP $

- US, $398
- China, $121
- Japan, $149
- Other EU, $126
- Korea, $44
- Germany, $82
- France, $46
- U.K., $40
- All Other, $146

Total World R&D = $1,151 billion

Source: OECD, Main Science and Technology Indicators, February 2011.
World = OECD members plus Argentina, China, Romania, Russian Federation, Singapore, South Africa, Taiwan.
Calculated using purchasing power parities.
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Trends in Federal R&D
percent of GDP


FY 2011 and FY 2012 figures are latest estimates.

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National R&D Investment
percent of GDP

Source: OECD, Main Science and Technology Indicators, February 2011.
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Communication Among Scientists

- Collaboration
- Scientific Meetings
- Peer reviewed Journals
  - Cornerstone of science
Dimensions ……

http://youtu.be/0fKBhvDjuy0
Powers of ten
Michio Kaku about future civilization
http://youtu.be/QI6vANpHhOA

What is space...Brian Greene...

http://www.youtube.com/watch?v=PGNxgm3tdG0