



Why Should You Be Scientifically Literate?

Robert M. Hazen

article highlights

Why should you care about being scientifically literate? It will help you

- understand issues that you come across daily in news stories and government debates
- appreciate how the natural laws of science influence your life
- gain perspective on the intellectual climate of our time

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Newspaper headlines on November 21, 2002:

We live in an age of scientific discovery.

- Boxing the genome code (*Sydney Morning Herald*, Australia)
- Scientist to attempt creation of living cell (*New York Times*, USA)
- 2 black holes may collide, say astronomers (*Times of India*)
- Ottawa unveils updated Kyoto plan (*Toronto Star*, Canada)
- 'Death gene' discovery (*Daily Telegraph*, UK)

Scientific issues are the subject of many debates.

We live in an age of constant scientific discovery — a world shaped by revolutionary new technologies. Just look at your favorite newspaper. The chances are pretty good that in the few days you'll see a headline about global warming, cloning, fossils in meteorites, or genetically engineered food. Other stories featuring exotic materials, medical advances, DNA evidence, and new drugs all deal with issues that directly affect your life. As a consumer, as a business professional, and as a citizen, you will have to form opinions about these and other science-based issues if you are to participate fully in modern society.

Scientific literacy helps us understand the issues.

More and more, scientific and technological issues dominate national discourse, from environmental debates on ozone depletion and acid rain, to economic threats from climate change and invasive species. Understanding these debates has become as basic as reading. Citizens need to be scientifically literate to:

- appreciate the world around them
- make informed personal choices

It is the responsibility of scientists and educators to provide everyone with the background today and tomorrow. What is scientific literacy? Why is it important? And how can we achieve it?

What is scientific literacy?

Scientific literacy, quite simply, is a mix of concepts, history, and philosophy that help you

Scientific literacy means a broad understanding of basic concepts.

Using science, not doing science, is the core of scientific literacy.

Some scientists are so focused in one area that they lack scientific literacy.

College graduates, as well, fall short on science basics.

The average American fails the grade, too.

- Scientific literacy is not the specialized, jargon-filled esoteric lingo of the experts. appreciate the importance of medical advances, nor do you need to be able to calculate in space exploration.
- Scientific literacy is rooted in the most general scientific principles and broad knowledge. It possesses facts and vocabulary sufficient to comprehend the context of the daily news.
- If you can understand scientific issues in magazines and newspapers (if you can do so with the same ease that you would sports, politics, or the arts) then you are scientifically literate.

Admittedly, this definition of scientific literacy does not satisfy everyone. Some academics value mathematical rigor and complex vocabulary. They want everyone to experience this taste of rigor. Those who insist that everyone must understand science at a deep level are confusing two concepts. In many other endeavors, *doing* science is obviously distinct from *using* science; and scientific literacy is not the same as doing science.

Surprisingly, intense study of a particular field of science does not necessarily make one scientifically literate. To a degree to which working scientists are often woefully uninformed in scientific fields outside their own. I asked a group of twenty-four Ph.D. physicists and geologists to explain the difference between DNA and RNA in molecular biology. I found only three colleagues who could do so, and all three of those individuals were geologists. And I'd probably find the same sort of discouraging result if I asked biologists to explain the difference between a superconductor and an insulator. The education of professional scientists is often just as narrowly focused as that of the general public. Scientists are just as likely to be ignorant of scientific matters outside their own specialty as are the general public.

In considering what scientific literacy is, it's also useful to recognize what it is not. Scientific literacy is not the ability to deal with everyday devices such as computers and VCRs. Technological literacy is a different matter, distinct from my definition of scientific literacy.

The scope of the problem

By any measure, the average American is not scientifically literate, even with a college degree.

- At a recent Harvard University commencement, an informal poll revealed that fewer than 10% of graduates could explain why it's hotter in summer than in winter.¹
- A survey taken at our own university (George Mason University), where one can find a higher percentage of scientists than at some other institutions, shows results that are scarcely more encouraging. The survey on scientific literacy could not correctly identify the difference between an atom and a molecule.

I suspect that these results are the rule, not the exception. Most colleges and universities have a high percentage of scientifically illiterate students who are incapable of understanding many of the important concepts of science at graduation.

The problem, of course, is not limited to universities. We hear over and over again about how poorly our students fare when compared to students in other developed countries on standardized tests. The most recent statistics estimate the numbers of scientifically literate Americans to be:³

- fewer than 7% of adults
- 22% of college graduates
- 26% of those with graduate degrees

The number of Americans who are scientifically literate by the standards of these studies is far lower than what you might hear as the anecdotes. Americans at all academic levels have not been given the basic background in science that we need to lead in the twenty-first century.

Why is scientific literacy important?

Why should we care whether our citizens are scientifically literate? Why should you care about arguments might convince you why it is important:

Scientific literacy is important.

- from civics
- from aesthetics
- from intellectual coherence

Civics

The general welfare of a nation is stronger with a citizenry that is scientifically informed.

The first argument from civics is the one I've used thus far. We're all faced with public issues and therefore we all should have some level of scientific literacy. Our democratic government, scientific research, manages natural resources, and protects the environment, can be thwarted by an uninformed electorate (not to mention a scientifically informed legislature) some of the most

Aesthetics

Understanding science enriches our appreciation of everyday activities.

The argument from aesthetics is less concrete, but is closely related to principles that are of our view, our world operates according to a few over-arching natural laws. Everything you do, even in the morning to the moment you go to bed at night, conforms to these laws of nature. Our science is grand and elegant and it represents a crowning achievement of human civilization. You can share in this from appreciating the unity between a boiling pot of water on a stove and the slow march of a butterfly's wing and the behavior of the fundamental constituents of matter. A scientific literacy is an enriching part of life, just as surely as a person who cannot read.

Intellectual Coherence

The intellectual climate of our era is influenced by our understanding of science.

Finally, we come to the third argument — the idea of intellectual coherence. Our society is in part defined by the ideas that they often play a crucial role in setting the intellectual climate of an era. For example, the Renaissance played an important role in sweeping away the old thinking of the Middle Ages and ushering in the modern world. The discovery of the mechanism of natural selection at once made understanding nature easier. The development of quantum mechanics have made our natural world seem (at least superficially) more coherent. The intellectual tenor of the times — what Germans call the *Zeitgeist* — was influenced by developments in science. The deep underlying threads of intellectual life in his or her own time without understanding

So what to do?

Science educators are providing ways to improve science literacy.

The problem has been defined and the need for a solution is real. How can you and your fellow science educators the world over have spent the last decade in an all-out assault on the problem, a

K-12 Education

U.S.'s National Science Education Standards emphasize the learning of concepts & principles through inquiry.

At the level of K-12 education, the National Research Council, in conjunction with the American Association of Science Teachers and other national teacher organizations, produced the sweeping *National Science Education Standards* for new science curricula for elementary, middle and high schools — curricula that emphasize concepts and principles rather than vocabulary and rote memorization. Gradually, school systems across the nation while numerous programs at the local and state levels seek to retrain teachers in this powerful way. In the future, our nation's students will demonstrate a richer appreciation of science than ever before.

Higher Education

Higher education is fostering student scientific literacy.

Reforms have also been targeted at the college level. In 1990, I joined forces with physicist Robert Serber and others to create "Great Ideas in Science." A companion textbook, *The Sciences: An Integrated Approach*, is now being used in many colleges. And hundreds of other institutions of higher education are engaged in their own experiments

The General Public

Science resources are

many and easily
available to the public.

**Conclusion: Everyone
should share in the
adventure of science.**

And what about those of us who are beyond college years? Today there are amazing resources and science journalists present every field of science to general readers. Wondrous television scientific research. And the internet abounds with science web sites that elucidate every cell exploration and particle physics to applied aspects of medical technologies, environmental hundreds of other important topics.

Thanks to these efforts the ball is in your court. With a little effort, you can share in the most species — the adventure of science.

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- Read how citizen science projects help to advance scientific literacy.
- To make progress, scientists and science educators need to build trust and empower using a variety of media formats.
- Some non-science-major biology and genetics courses show limited effectiveness.
- The need for environmental literacy is discussed here.
- Remember using the scientific method? Read why it should be the basis for the integ
- A reviewer extols the virtues of a key book about teaching environmental literacy.
- Joel Cracraft explains how creationism in all its forms is not a scientific worldview, but public schools.

learnmore links

“Improving Scientific Literacy and Conservation in Developing Nations”

Carlos de la Rosa discusses, in an article on our site, the problems with scientific literacy in developing nations and suggests <http://www.actionbioscience.org/newfrontiers/delarosa.html>

Ask a Biologist

It is designed as an educational resource for students K-12, and their teachers and parents. Check out their <http://askabiologist.asu.edu/>

“Science and Technology: Public Attitudes and Public Understanding”

Read the highlights from Science and Engineering Indicators 2006, by The National Science Foundation, for an analysis. The second link takes you to a related news article about the findings.

<http://www.nsf.gov/statistics/seind06/c7/c7h.htm>

http://www.space.com/scienceastronomy/generalscience/us_science_020501.html

Scientific literacy for everyone

The Foundation for Scientific Literacy has as its mission to educate, support, and promote scientific literacy, defined as the concepts and processes required for personal decision-making, participation in civic and cultural affairs, and economic

<http://www.scientificliteracy.org/>

Trends in International Mathematics and Science Study (TIMSS)

Find out about the largest international study of student achievement — which countries participated, how student achievement was collected, and how to obtain the results.

<http://timss.bc.edu>

For educators: Improving science literacy

The NSTA position paper “Teaching Science and Technology in the Context of Societal and Personal Issues” offers suggestions within the context of societal and personal issues in order to allow students the ability to use and apply science and technology.

<http://www.nsta.org/about/positions/societalpersonalissues.aspx>

Beyond Discovery

A series of articles from the National Academy of Sciences explores “the crucial role played by basic science, the application of science, and the time the original research was conducted.”

<http://www.beyonddiscovery.org/>

Science basics

The American Association for the Advancement of Science (AAAS) has made its publication, *Science for all Americans*, available online, from mathematics to biology.

<http://www.project2061.org/tools/sfaaol/sfaatoc.htm>

Your Genes, Your Choices

A publication of the Science + Literacy for Health Project, *Your Genes, Your Choices* “describes the Human Genome Project and the social issues that are raised by the project.” Click on “table of contents” to read each chapter online.

http://www.oml.gov/TechResources/Human_Genome/publicat/genechoice/index.html

Guide to Biotechnology

“Guide to Biotechnology” from the Biotechnology Industry Organization provides an overview about biotechnology. No. 1000 technologies and their applications, and ethics.

<http://www.bio.org/speeches/pubs/er/>

Read a book: general

» *Science Matters: Achieving Scientific Literacy*, by Robert M. Hazen and James Trefil, presents basic scientific concepts.

» *The Pleasure of Finding Things Out*

This collection of previously unpublished or difficult-to-find short works by maverick physicist and Nobel Laureate Richard Feynman, written in a humorous, anecdotal way. (Perseus Books, 2000)

Read a book: for educators

Global Science Literacy, edited by Victor J. Mayer, proposes an international science curriculum concept, with sample ideas.

International Center for Scientific Research

“The only portal that references all scientific organizations around the world, listed by country and topic” — in four languages.

<http://www.cirs-tm.org>

getinvolved links

Parents & Kids: online science field trips and more

TryScience.org provides a database of over 400 science centers worldwide so that kids can “investigate, discover, and try” virtual field trips and live webcams of exhibits.

http://www.tryscience.org/fieldtrips/fieldtrip_home.html

Science trivia

Looking for a fun way to get your students or children curious about science?

<http://sciencespot.net/Pages/triviatogo.html>

Sally Ride Science Festivals

Held throughout the country, the festivals bring middle school girls together for a day of science and socializing. Festivals feature scientists, microbiologists, and engineers; a street fair with activities, food, and music; and more. For more information and a list of festivals, visit <http://www.sallyridefestivals.com>

<http://www.sallyridefestivals.com>

Awesome Library: Science Lessons

The Awesome Library organizes the Web with carefully reviewed resources. Special sections for students, teachers and parents are available. For more information, visit http://www.awesomelibrary.org/Library/Materials_Search/Lesson_Plans/Science.html

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Adopt a classroom

This non-profit site provides opportunities for individuals and corporations to donate funds or provide other support to help purchase science supplies in the U.S. Also, teachers can register their class needs online.

<http://www.adoptaclassroom.com/>

For educators: Hollywood science

This site, created by the BBC, is devoted to movie clips that depict scientific concepts, with suggestions for classroom use.

http://www.open2.net/science/hollywood_science/

For educators and students: The Science Club

The club offers science projects and activities for children, as well as a science fair ideas exchange. Includes links to materials and resources.

<http://www.scienceclub.org/>

Science Adventures

This site's goals are "to develop partnerships with parents, teachers, and schools in an effort to raise science literacy" and "to provide science resources for K-6 grades."

<http://www.scienceadventures.com/>

For educators/researchers: science events database

"A free, fully searchable, multi-disciplinary scientific events database" including conferences on zoology conferences, life sciences, and more. "Browse events, order brochures, register and purchase proceedings papers online."

<http://www.nature.com/nature-events/>

For high school students

Join the Science National (US) Honors Society or start a society chapter at your high school.

<http://www.scienceNHS.org>

educatorresources

ActionBioscience.org original lesson

Activities related to the article by Robert Hazen were written by ActionBioscience.org staff. The lesson includes article content and a set of activities that involve scientific inquiry, research, and photography.

Lesson Title: *Why?*

Levels: middle school and up to grade 10

Summary: The lesson is titled "Why?" because students are full of wonder about the world. However, for curriculum purposes, the lesson focuses on the nature of science through the spirit of inquiry. The handout activities are designed as a game where students search for and take photographs of scientific phenomena.

Download/view lesson.

(To open the lesson's PDF file, you need [Adobe Acrobat Reader](#) free software.)

Useful links for educators

- » For educators and students who need some help with photography, downloading photos, and editing photos:
 - Basic digital photography guide: <http://photonhead.com/beginners/>
 - Editing photography basics: <http://www.shortcourses.com/editing/index.htm>
- » The Scientific Method (ideas for discussion about how scientists conduct inquiry):
<http://school.discovery.com/sciencefaircentral/scifairstudio/handbook/scientificmethod.html>
- » The Nature of Science (discussion ideas about inquiry and what science is):
<http://www.project2061.org/publications/sfaa/online/chap1.htm>

Useful links for student research

In addition to the links in the “learn more” section above:

- » How Stuff Works (ideas for questions): <http://www.howstuffworks.com/>
- » Encyclopedia of Life (more ideas): <http://www.eol.org/>
- » Great Scientists: http://dimdima.com/science/science_common/show_science.asp?q_search=Great+Scientist
- » Great Women Scientists: <http://www.astr.ua.edu/4000WS/>
- » Great Inventors: <http://library.christchurch.org.nz/kids/inventions/>
- » People who won the Nobel Prize: <http://nobelprize.org/>

articlereferences

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