STATE BOARD OF EDUCATION

HEARING TYPE: _X___ INFORMATION/NO ACTION

DATE: MARCH 12-13, 2007

SUBJECT: **SCIENCE LITERACY**

SERVICE UNIT: State Board of Education
Edie Harding, Executive Director

PRESENTERS: Theresa Britschgi, Director, BioQuest
Dr. Lynda Paznokas, Associate Dean, Washington State University
Ethan Smith, Teacher, Tahoma High School
Roy Beven, Science WASL Manager, OSPI
Eric Wuersten, Program Supervisor, Science, OSPI

BACKGROUND

In 2005, the Legislature created *Washington Learns* to conduct a comprehensive review of the state's entire education system. One recommendation emerging from that work focused on the need for Washington students to be better prepared in mathematics and science by meeting standards "at least as high as those in other states and nations." *Washington Learns* directed the State Board of Education (SBE) to adopt international performance standards for mathematics and science benchmarked to the Trends in International Mathematics and Science Study (TIMSS) or the Programme for International Student Assessment (PISA) by December 2007. It also called for the SBE to adopt high school graduation requirements aligned with those standards.

But why does science matter? Presentations from five panelists will provide a variety of perspectives on that topic, including what it means to be literate in science. Two articles on science literacy have been included in your packet to help you begin thinking about these issues.

Theresa Britschgi is Director of BioQuest, a science education outreach component of the Seattle Biomedical Institute. She will talk about why science literacy is important in daily life and in the workplace. Ms. Britschgi was a member of the Washington State Science System Plan team that developed *Science Matters*, the state's science learning system.

Lynda Paznokas is Associate Dean of the College of Education at Washington State University. She will talk about why science literacy is important for success in college, and will allude to the science college readiness definitions that have recently been developed under the leadership of the Higher Education Coordinating Board. Dr.

Paznokas was a member of the Washington State Science System Plan team that developed *Science Matters.*

Ethan Smith is a teacher at Tahoma High School where he teaches Anatomy and Physiology to 12th graders, Inquiry Science to 10th graders, and Astronomy to 11th and 12th graders. He will bring the discussion home to the classroom, talking about his efforts to help his students become science literate. Mr. Smith was a member of the Science Curriculum Framework Team that built the current Science Grade Level Expectations (GLEs).

Roy Beven is the Science Washington Assessment of Student Learning (WASL) Manager with the Office of Superintendent of Public Instruction (OSPI). Using the context of a sample WASL science question, he will talk about what elements of science literacy are reflected in the state's approach to science assessment.

Eric Wuersten is Program Supervisor for Science with OSPI. He will talk about current high school graduation requirements, and the implications of those requirements for science literacy.

M E M O R A N D U M

DATE: March 13, 2007

TO: State Board of Education Members

FROM: Eric Wuersten, Program Supervisor, Science
Office of Superintendent of Public Instruction

RE: Science Overview

The purpose of this memorandum is to provide an overview of the development of Washington's science standards.

I. Development of K–12 Science Standards

The following timetable provides a quick snapshot of the development of Washington's K–12 science standards.

1993 Washington State Legislature defined the basic education goals to include science.
1997 Washington State Legislature adopted science Essential Academic Learning Requirements (EALRs).
2001 No Child Left Behind (NCLB) required states to conduct a valid and reliable science assessment, based on rigorous science standards, by 2008 in grade bands 3-5, 6-8, and 9-12.
2001 Washington State Legislature required students graduating in 2010 to pass the science Washington Assessment of Student Learning (WASL).
2002 EALRs reviewed by national experts from Mid-Continent Research for Education and Learning (McREL).
2005 Grade Level Expectations (GLEs) added to the EALRs to meet specificity requirements of NCLB and the science WASL.

II. Science Essential Academic Learning Requirements

The science standards were refined based on the recommendations of McREL and are now defined by three EALRs: Systems, Inquiry and Application.

EALR 1 - Systems: Students gain an understanding of the natural world as interconnected and nested systems made of interacting parts. Scientific concepts and principles explain how the inputs, outputs, transfers, and transformations of matter, energy and information occur in the systems of the natural world.

EALR 2 - Inquiry: Students gain deep understanding of scientific concepts and principles as they learn to investigate systems.

EALR 3 - Application: Students gain an ability to apply their understanding of systems and inquiry to design solutions to human problems in societal and environmental contexts.

A panel of 53 K-20 science educators and business leaders worked for three years to develop the Grade Level Expectations (GLEs), adding specificity to the EALRs. The GLEs were then reviewed for cultural bias by a panel of 12 people representing diversity across Washington State. In addition, a panel of national science education experts reviewed the GLEs.

III. Development of a Science Strategic Plan: *Science Matters*

In 2003 the Office of Superintendent of Public Instruction (OSPI) convened a panel of state science leaders from business and K–20 to develop a plan for a science learning system. The goal was to provide all students an opportunity to achieve science literacy, defined for this purpose as meeting standard on the WASL. Over two years, the panel conducted five statewide surveys and 12 focus groups with elementary and secondary science teachers, K–12 administrators, pre-service teachers and higher education administrators.

Based on feedback received from the surveys and focus groups, the panel designed a strategic statewide plan for a science learning system, *Science Matters* (see Figure 1). This strategic plan assures all students the opportunity to achieve science literacy in 2010 by providing:

- **Professional development** of the highest quality and teacher preparation adequate in science
- **Instructional material support**—high quality, research-based, aligned with standards, with instructional modules (Powerful Classroom Assessments or PCAs) and other materials that fill critical curriculum gaps.
- **Strategic planning and capacity building** to create an infrastructure that builds administrative, school, district, ESD, university, and community support for science
- **Evaluation for continuous improvement,** including assessment preparation that supports the WASL and assures that the system is operating to achieve its primary goal: science literacy for all.

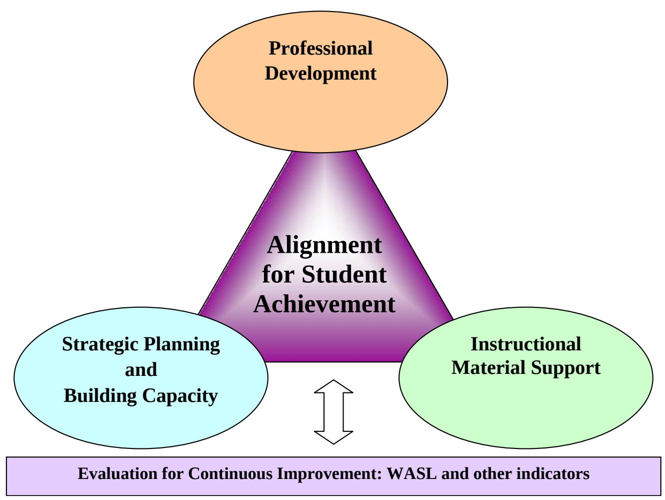


Figure 1: Key Components of *Science Matters*

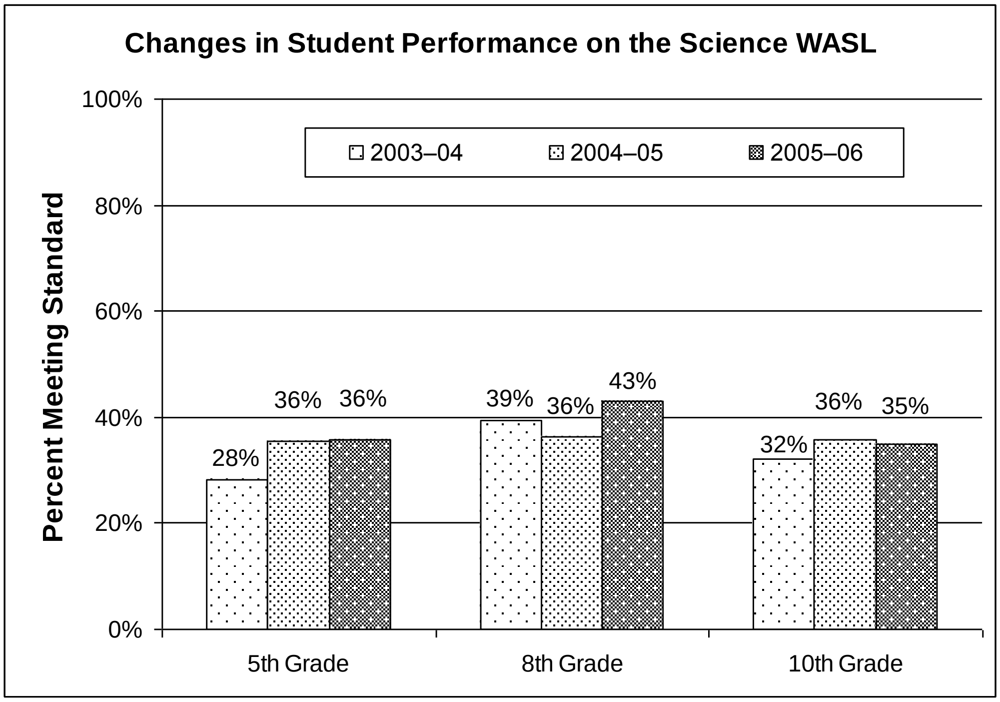
IV. What We Know About Science Preparation and Performance

In 2002 the Office of Curriculum and Instruction at OSPI surveyed administrators in 88 Washington school districts, representing 284,978 students. One finding was that ninth and tenth grade students do not take science each year.

- 36% take 2–3 semesters of science
- 60% take 4 semesters of science

Among the districts surveyed, students in ninth grade (60%) were most likely to take physical science, while those in tenth grade (88%) tended to take biology.

These course-taking patterns may be a factor in student WASL performance. In 2006, 64% of tenth graders did not meet standard on the science WASL. The graph below illustrates changes in student performance on the science WASL over three years.



Source: OSPI Web site

Although student performance increased between fifth and eighth grade in the 2005–06 school year, it decreased between eighth and tenth grade. Assuming that many of the students who took the 2004 WASL in eighth grade are the same students who took the 2006 WASL, why did their performance decrease? We do not yet know the answers to these questions.

The focus of teachers' knowledge and preparation in connection to the EALRs may also help explain student performance. First, teachers' content knowledge is usually narrowly focused on one academic discipline (e.g., biology, chemistry, earth science, etc.). The EALRs expect students to understand *systems* that connect science across the disciplines. For example, a biology teacher teaching evolution may not know the theory of plate tectonics (generally learned in geology) that is needed to explain the occurrence of similar fossils in different continents. Second, few teachers are trained on scientific *inquiry*—how to conduct scientific investigations—and yet that knowledge is an important component of the science EALRs, and is measured on the WASL. Third, the systems approach that we advocate in our standards emphasizes *application*—how we use science to solve real-world problems. Traditional academic disciplines often place greater emphasis on concepts and principles than on application.

For these reasons, professional development and instructional material support are components critical to the success of the strategic plan, *Science Matters.* Research has shown that the most significant determinant of student achievement is an effective teacher.

V. Development of College Readiness in Science

The Higher Education Coordinating Board (HECB), in collaboration with representatives of the OSPI and the Council of Presidents, has been engaged in initiatives to define the skills and knowledge students need to be prepared for entry-level college coursework in mathematics, science and English. These definitions are intended to align with K–12 learning goals expressed in the EALRs and GLEs. However, GLEs beyond tenth grade have been established only for mathematics.

The HECB has been part of the management team providing oversight of the Transition Mathematics Project, led by the State Board for Community and Technical Colleges. Since 2006, the HECB has been working with teams of K–12 and college teachers to develop college readiness attributes and definitions in science and English. This first phase of the project has culminated in the publication of preliminary college readiness attributes and definitions—preliminary only because they have not yet been piloted in classroom settings.

The science college readiness "how to learn" attributes build on and expand slightly those established by the Transition Math Project. The eight attributes specify that students will demonstrate intellectual engagement, take responsibility for his or her own learning, persevere through the learning process, pay attention to detail, demonstrate ethical behavior, communicate effectively across a variety of audiences and purposes, effectively read and organize information presented in questions/problems in order to formulate solutions, and build creative solutions to intellectual and practical real-world problems.

College readiness–"what-to-learn" definitions–focus on "big ideas" in science—core science concepts in physical, life and earth/space sciences. They also identify foundational skills in scientific inquiry and the nature of science, science and society, quantitative analysis, technology, and communication.

If funding is secured from state and private sources, Phase 2 activities in the 2007–2009 biennium would include three primary tasks: 1) piloting the definitions in 11^{th} and 12^{th} grade classrooms, 2) developing a research design to compare high school and college performance of students exposed to college readiness learning experiences to the performance of students who hadn't participated in the pilots, and 3) planning professional development training to be implemented in the third phase of the project.

VI. Summary and Emerging Questions

Washington has in place K-12 standards (EALRs), GLEs through the tenth grade, and a strategic plan (*Science Matters)*. The higher education community has established a preliminary set of college readiness definitions and attributes in science. As the Board considers the place of science in a meaningful high school diploma, questions such as the following are likely to arise.

- How much science is sufficient to achieve science literacy?
- What qualifies as a high school science course?
- What qualifies as high school lab science course?
- Does our system have the capacity to offer science classes to all ninth and tenth graders?
- How can high school graduation requirements assure opportunity for all students to achieve science literacy?

Kathe Taylor

From: Edie Harding
Sent: Monday, February 19, 2007 11:15 AM
To: Kathe Taylor
Subject: Good article on science literacy

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authorbio
Robert M. Hazen, Ph.D., is a research scientist at the Carnegie Institution of Washington's Geophysical Laboratory and Clarence Robinson Professor of Earth Science ...
more on author

new frontiers: bioscience literacy for all

Why Should You Be Scientifically Literate?

By Robert M. Hazen

An ActionBioscience.org original article

articlehighlights

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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December 2002

Why Should You Be Scientifically Literate?

By Robert M. Hazen

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)

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 next 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 issues are the subject of many debates.

More and more, scientific and technological issues dominate national

Scientific literacy helps us understand the issues.

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. All 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 knowledge to help us cope with the fast-paced changes of today and tomorrow. What is scientific literacy? Why is it important? And how can we achieve scientific literacy for all citizens?

What is scientific literacy?

Scientific literacy, quite simply, is a mix of concepts, history, and philosophy that help you understand the scientific issues of our time.

Scientific literacy means a broad understanding of basic concepts.

- Scientific literacy is not the specialized, jargon-filled esoteric lingo of the experts. You don't have to be able to synthesize new drugs to appreciate the importance of medical advances, nor do you need to be able to calculate the orbit of the space station to understand its role in space exploration.
- Scientific literacy is rooted in the most general scientific principles and broad knowledge of science; the scientifically literate citizen 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 tackle articles about genetic engineering or the ozone hole with the same ease that you would sports, politics, or the arts) then you are scientifically literate.

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

Admittedly, this definition of scientific literacy does not satisfy everyone. Some academics argue that science education should expose students to mathematical rigor and complex vocabulary. They want everyone to experience this taste of "real" science. But my colleagues and I feel strongly that those who insist that everyone must understand science at a deep level are confusing two important but separate aspects of scientific knowledge. As in many other endeavors, *doing* science is obviously distinct from *using* science; and scientific literacy concerns only the latter.

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

Surprisingly, intense study of a particular field of science does not necessarily make one scientifically literate. Indeed, I'm often amazed at the degree to which working scientists are often woefully uninformed in scientific fields outside their own field of professional expertise. I once asked a group of twenty-four Ph.D. physicists and geologists to explain the difference between DNA and RNA -- perhaps the most basic idea in modern molecular biology. I found only three colleagues who could do so, and all three of those individuals did research in areas where this knowledge was useful. And I'd probably find the same sort of discouraging result if I asked biologists to explain the difference between a semiconductor and a superconductor. The education of professional scientists is often just as narrowly focused as the education of any other group of professionals, so scientists are just as likely to be ignorant of scientific matters outside their own specialty as anyone else.

In considering what scientific literacy is, it's also useful to recognize what it is not. Scientific literacy is often confused with technological literacy -- the ability to deal with everyday devices such as computers and VCRs. Technological literacy is important to many pursuits in modern society, but it is 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:

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

- At a recent Harvard University commencement, an informal poll revealed that fewer than ten percent of graduating seniors 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 argue that the teaching of undergraduates enjoys a higher status than at some other institutions, shows results that are scarcely more encouraging. Fully half of the seniors who filled out a scientific literacy survey could not correctly identify the difference between an atom and a molecule.[2]

I suspect that these results are the rule, not the exception. Most colleges and universities have the same dirty little secret: we are all turning out scientifically illiterate students who are incapable of understanding many of the important newspaper items published on the very day of their graduation.

The problem, of course, is not limited to universities. We hear over and over again about how poorly American high school and middle school students fare when compared to students in other developed countries on standardized tests. Scholars who make it their business to study such things estimate the numbers of *scientifically literate* Americans to be:[3]

The average American fails the grade, too.

- 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 distressingly low. The numbers, then, tell the same story as the anecdotes. Americans at all academic levels have not been given the basic background they may need to cope with the life they will have to lead in the twenty-first century.

Scientific literacy is important.

Why is scientific literacy important?

Why should we care whether our citizens are scientifically literate? Why should you care about your own understanding of science? Three different arguments might convince you why it 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 whose discussion requires some scientific background, and therefore we all should have some level of scientific literacy. Our democratic government, which supports science education, sponsors basic scientific research, manages natural resources, and protects the environment, can be thwarted by a scientifically illiterate citizenry. Without an informed electorate (not to mention a scientifically informed legislature) some of the most fundamental objectives of our nation may not be served.

Aesthetics

Understanding science enriches our appreciation of everyday activities.

The argument from aesthetics is less concrete, but is closely related to principles that are often made to support liberal education. According to this view, our world operates according to a few over-arching natural laws. Everything you do, everything you experience from the moment you wake up in the morning to the moment you go to bed at night, conforms to these laws of nature. Our scientific vision of the universe is exceedingly beautiful and elegant and it represents a crowning achievement of human civilization. You can share in the intellectual and aesthetic satisfaction to be gained from appreciating the unity between a boiling pot of water on a stove and the slow march of the continents, between the iridescent colors of a butterfly's wing and the behavior of the fundamental constituents of matter. A scientifically illiterate person is effectively cut off from an immensely 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 inextricably tied to the discoveries of science -- so much so that they often play a crucial role in setting the intellectual climate of an era. For example, the Copernican concept of the heliocentric universe played an important role in sweeping away the old thinking of the Middle Ages and ushering in the Age of Enlightenment. Similarly, Charles Darwin's discovery of the mechanism of natural selection at once made understanding nature easier. And in this century the work of Freud and the development of quantum mechanics have made our natural world seem (at least superficially) less rational. In all of these cases, the general intellectual tenor of the times -- what Germans call the Zeitgeist -- was influenced by developments in science. How can anyone hope to appreciate the deep underlying threads of intellectual life in his or her own time without understanding the science that goes with it?

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 family become scientifically literate? Fortunately, science educators the world over have spent the last decade in an all-out assault on the problem, and a number of solutions are at hand:

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 for the Advancement of Science and national teacher organizations, produced the sweeping *National Science Education Standards*.[4] This farsighted document serves as a building code for new science curricula for elementary, middle and high schools -- curricula that emphasize an inquiry-based approach in the context of concepts and principles rather than vocabulary and rote memorization. Gradually, school systems around the country are retooling their science courses, while numerous programs at the local and state levels seek to retrain teachers in this powerful new educational approach. Soon, educators hope, our nation's students will demonstrate a richer appreciation of science than ever before.

Higher education is fostering student scientific literacy.

Higher Education

Reforms have also been targeted at the college level. In 1990, I joined forces with physicist James Trefil in developing one integrated science course, "Great Ideas in Science." A companion textbook, *The Sciences: An Integrated Approach*, is now used in approximately 200 colleges and universities.[5] And hundreds of other institutions of higher education are engaged in their own experiments to foster scientific literacy among college graduates.

Science resources are many and easily available to the public.

The General Public

And what about those of us who are beyond college years? Today there are amazing resources for continuing education. Scores of books by scientists and science journalists present every field of science to general readers. Wondrous television and radio programs explore the latest advances in scientific research. And the internet abounds with science web sites that elucidate every conceivable scientific topic, from the pure research of space exploration and particle physics to applied aspects of medical technologies, environmental hazards, materials development, drug design, and hundreds of other important topics.

Conclusion: Everyone should share in the adventure of science.

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

About the author: Robert M. Hazen, Ph.D., is a research scientist at the Carnegie Institution of Washington's Geophysical Laboratory and Clarence Robinson Professor of Earth Science at George Mason University, Virginia. He received his B.S. and M.S. in geology from the Massachusetts Institute of Technology (1971), and a Ph.D. from Harvard University in earth science (1975). Author of more than 230 articles and 16 books on science, history, and music, including *Why Aren't Black Holes Black?: The Unanswered Questions at the Frontiers of Science*, Hazen also investigates possible roles of minerals in the origin of life.
http://www.geol.vt.edu/stuinfo/hazenbio.html
http://hazen.gl.ciw.edu/gmu/

For the Success of Each Learner

Educational Leadership

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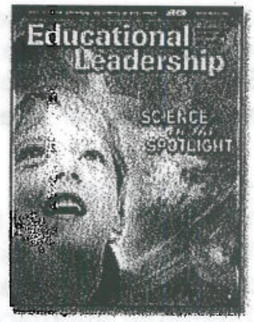

December 2006/January 2007

Understanding the Scientific Enterprise: A Conversation with Alan Leshner

Deborah Perkins-Gough

Listen to an audio clip from this interview:

RealPlayer | Windows Media

When Alan Leshner became chief executive officer of the American Association for the Advancement of Science (AAAS) in 2001, he stated that one of his goals was "to expand people's understanding of the enterprise of science and increase appreciation of the way in which science is involved in American life." Leshner has promoted the role of science and science education over the course of his extensive career in public policy as a senior official with the National Science Foundation, Deputy Director and Acting Director of the National Institute of Mental Health, and Director of the National Institute on Drug Abuse. In this interview with Educational Leadership, *he offers his views on the importance of science literacy, the challenges facing science educators, and the best ways to get students excited about science.*

You've written that "virtually every major issue facing global society today has science and technology at its core." What are some of those issues?

Science and technology are so embedded in everyday life that people don't even think about them. Many consumer issues are science issues, and so are many health care choices. How will you know whether some medical treatment is a scam, or whether it's real? Suppose you want to buy a video game system for your kid—how will you decide which one to buy? Will you just go by what's most popular, or will you be able to make an informed judgment? If you buy cosmetics, how do you know that a product is safe? That's a question that depends on scientific testing.

People also need to know enough about science issues to be able to participate fully as citizens. For example, most people may not need to know all the details of embryonic stem cell research or cloning, but they do need to know enough about embryo development or in vitro fertilization to understand alternative positions on those issues. The same is true for climate change. How do we know whether the earth is really warming?

You need at least a familiarity and comfort with science to tackle many of the activities and issues of modern life. Even though you don't need to know the details of every scientific conundrum, you need an awareness of what is and isn't science.

What do people need to understand about what science is and what science isn't?

You need some fundamental understanding about the scientific enterprise. What's science all about? What are its limits? When someone claims that something is science, how will you know whether that's true?

The purpose of science is to answer our questions about the nature of the world—whether we like the answers or not. Science has discrete limits; it's limited to natural explanations about the natural world. Some scientists violate that rule and claim that science has something to say about God. Or that science has something to say about when life begins. Well, we don't really know the answers to those questions, and they're not amenable to scientific investigation.

Does the public have misperceptions about scientists and the scientific enterprise?

It's interesting that every survey that's been done has shown that members of the public have great regard for science. Since the 1970s, the studies published by the National Science Board show that between 70 and 90 percent of the U.S. population believe that the benefits of science outweigh its risks. The problem is, large percentages of the public have no idea what is and isn't science. Over 40 percent believe that astrology is scientific and that extrasensory perception has been studied scientifically. And 47 percent answer "no" to the question of whether humans evolved from earlier species.

Intelligent Design is an example of a misunderstanding about what is and isn't science. Its proponents claim that it's a scientific theory, an alternative theory of evolution. There's nothing scientific about Intelligent Design—it doesn't even address a scientific question. But when you talk to people, they say, "Oh, shouldn't we teach both theories? Isn't this a matter of fairness?" Talking about both ideas might be a matter of fairness in the living room or in a philosophy classroom, but in the science classroom you would be comparing science and non-science. You wouldn't be doing science, you'd be doing philosophy.

Intelligent Design advocates argue that because evolution is just a "theory," science courses should teach about the flaws in that theory. What do you think about that claim?

It's really unfortunate that the word *theory* is an English vernacular term as well as a scientific term. For something to be a theory in science, thousands of studies must have been done. Establishing a theory requires a great amount of empirical observation and experimental testing of diverse hypotheses. You don't get to call something a theory until it's been subjected to a rigorous amount of scientific study. In the English language, however, a theory could be anything. So your theory might be evolution, and my theory—let's pretend that I developed it this morning in the shower—might be that people came to be because of the Great Spaghetti Monster. Well, that may be true; who knows? But that's not a scientific theory. Scientists get to call something a scientific theory—for example, gravity or the big bang—only after a tremendous amount of preparatory work.

What advice would you give teachers who are challenged by students, parents, or school boards when they teach about evolution?

Teachers are at times facing phenomenal pressure. The best defense is information, and AAAS does have on our Web site some powerful resources to support teachers, including Project 2061's *Abbreviated Guide for Teaching Evolution* (www.aaas.org/news/press_room/evolution).

The controversy over teaching evolution seems to be just one aspect of a broader feeling among some sectors of the population that science comes into conflict with basic values. Is the tension between science and society growing?

Many of us in the scientific community are concerned that there's increased tension between science and society. In my view, the current increase in tension is coming about because scientific advances in many fields are beginning to encroach on issues of core human values. For example, as we learn more about biology, it raises issues about when you believe life began, or the essence of what life is, or what someone's "self" is.

I'm a neuroscientist, and in my field, what we learn about the biological bases of the mind has implications for our definition of the soul and our idea of personal responsibility. Those kinds of issues sometimes conflict with people's long-held beliefs about the world that are based on ethics or religion. As science gets closer to our core questions about the nature of life—for example, in embryonic stem cell research—it makes people more and more uncomfortable.

How do the tensions between science and society affect the recruitment and training of

new scientists? Are we experiencing shortages of people entering the sciences?

The scientific community has been concerned for a long time about recruiting the best and brightest students into the sciences. It's not just about absolute numbers; it's about getting the most talented students interested in science. And when excellent students live in households or communities where there is this kind of tension, it's easy for them to say, "I'll go into some other field where I don't have to confront these issues." In addition, funding for science is extremely tight now, so not only is science a difficult way of life, but also it's hard to be a scientist and compete for funding, for recognition, for promotion, for faculty jobs. If the societal context is difficult or tense, that reduces the enthusiasm for a scientific career.

The details of those tensions are different in different areas of the world. Studies like the European Commission's EuroBarometer 2005, the most recent analysis of public attitudes in Europe, show that public appreciation of science—the percentage of people who think that the benefits of science outweigh the risks—has actually decreased by 10 percentage points over the previous 10 years. And there's more overall skepticism of science and technology in Europe than in the United States.

But Europeans don't understand this whole tension around values issues. People in Europe ask us all the time, "Who would teach Intelligent Design in a science classroom?" On the other hand, they're very uncomfortable about genetically modified foods, whereas people in the United States are not. And they're much more uncomfortable about nanotechnology than we are.

So science raises moral and practical issues everywhere, and it always will. But the issues are different in different cultural contexts. Right now in the United States, because there's such a dominance in public discourse of religious issues and issues of faith, I think that's where science is abutting or encroaching on core values.

Should we take seriously claims that the United States is in danger of falling behind the rest of the world in science and technology? If so, what should we do about it?

Politicians frequently worry about who's the top scientific country in the world. But I'm the CEO of a global scientific society, so to me, the more countries that have first-rate scientific enterprises the better. My concern is that a failure of the U.S. government—or society at large—to support science at a sufficient level could undermine our very eminence, let alone our pre-eminence, in science.

For example, at a time when overall science funding is decreasing in the United States, other countries, such as China, are rapidly increasing their support. In 1992, China was 17th among countries of the world in its support of science; today it's 3rd. The European Union now outpublishes the United States in science. Whether that's good or bad, the United States will have to work hard to maintain its eminence. The United States has a very strong scientific enterprise, and it needs to work hard to keep it that way. That's the bottom line.

Let's talk about the role of elementary and secondary education. The American Association for the Advancement of Science has worked in K–12 education through Project 2061. Update us on that initiative.

Project 2061 has gone through an interesting evolution. Its first major report in 1989, *Science for All Americans*, began by tackling the question, What do students need to know in science when they graduate from high school? The next question was, What do they need to know at each level? So in 1993 *Benchmarks for Science Literacy* translated the *Science for All Americans* goals into learning benchmarks for grades K–12.

Now Project 2061 has completed an atlas that lays out the pathways from elementary school through high school—what students should learn at each level. You actually could tape the strand maps of this atlas up on the wall and say, OK, in 3rd grade, here's what we should be teaching; OK, we're in 5th grade, have we covered this? And you can trace that path. In fact, the strand maps have been so popular among teachers and curriculum developers that other countries are using them. We've been negotiating with our counterparts in China for a translation into Chinese so that they can use this atlas as well.

Most recently, we've been working on assessment tools so we'll know whether students have met the objectives and so we can make sure that assessments are systematically aligned to the objectives.

The objectives and the benchmarks developed by Project 2061 are used in many state standards documents. Whether the strand maps are being followed diligently, I don't know.

How do you think the new science testing requirements under No Child Left Behind are going to affect those state standards and objectives?

The National Academy of Sciences and Project 2061 have contributed a lot to establishing national guidelines that define the science knowledge and skills that students need. But are states, in fact, aligning their standards with the standards that have been established through a rigorous process involving educators and the scientific community? I'm sorry to say that not all states are doing that. We need to ask, What are states testing? What standards are their curriculums developed against? No one could argue with the general goals of No Child Left Behind, but it's the specific implementation that matters. And this may be heretical, but maybe we're providing too much freedom to individual states to do what they want and to interpret what No Child Left Behind means for themselves.

Project 2061 has been quite critical of science textbooks. Have science textbooks improved in response to those criticisms?

Project 2061's 1999 evaluation found that science textbooks covered many topics superficially and were full of disconnected facts. Because of their lack of depth, they were likely to bore students. In fact, all 10 of the most popular middle and high school science textbooks were rated as unsatisfactory.

It's difficult to know whether our assessments actually have changed textbooks. But I can tell you that when Project 2061 went through that exercise, it was a source of great concern not only to textbook writers and textbook publishers, but also to teachers using the textbooks. We're no longer evaluating textbooks in that way, but I hope that our evaluation has been a spur to textbook writers and adopters to try to make sure that we're providing the most modern science education that we possibly can. Project 2061 is now working to ensure that instructional materials are aligned with its science standards through our Center for Curriculum Materials in Science.

In addition to solid standards and aligned instructional materials, another key component of good science education is the teacher. What skills do elementary and secondary school science teachers need to get students excited about science?

I'm not an expert on teacher training, but I do know that if you ask successful scientists what brought them into science, every one of them says a teacher. There is not one established scientist I know who does not credit—or blame—a teacher for his or her career choice.

The question is not only what qualifications the teacher has, but also what the teacher does in the classroom. Again, I have to come back to the importance of teaching not only about scientific content, but also about science itself. What does it mean to have a scientific way of life? What does it mean to think about things in a scientific way?

Most established scientists had either a research experience or a problem-solving experience early on in their education—a sort of eureka moment when we realized that science is fun. That's a trite expression, I know, but the truth is, science *is* fun. But you have to show students that it's fun; you can't just assert that it's fun.

In my case, my decision to become a scientist had to do with a college undergraduate research experience, when a psychology professor, Dr. Charles Stewart, brought me into his lab and made me a junior partner in his research. At the time, we didn't really understand how lower organisms learned and remembered things, and we were trying to figure out the biological basis of memory processes in flatworms—planaria—which are very simple organisms. Dr. Stewart involved me in every aspect of the project, from its initial conceptualization to building the apparatus to running the study to analyzing the data, and then we actually published a paper together. He spent tremendous amounts of time with me sharing his thought processes and other aspects of his life as a scientist. What more could a young student ask for? It was inspiring. And the core of the experience was that it was fun.

In elementary and middle school, we often worry so much about getting little facts in that we neglect to show the problem-solving excitement of science. You know, many of us who work in science get to play with lots of really nifty toys. Doing chemical assays is fun because you see the magical results. So the key is finding a way to transmit to students the excitement of science and scientific discovery and the sheer fun of doing and thinking science.

My view is that the earlier you can expose young people to scientific problem solving, the better—the more interesting they will find science. They'll build on those early experiences later on.

What exciting fields of science should today's students know about as they consider a science career?

That's really tough. Progress in the life sciences has been unbelievable in the last few decades. We've seen the sequencing of the genome and the tremendously rapid pace of discovery in understanding the brain. But we've also had tremendous excitement in physics, chemistry, and material science, where we're developing new materials all the time and understanding the properties of materials.

Sometimes it's hard for young people to understand the excitement. In physics, for example, much depends on sophisticated mathematics. But I go to a lot of lectures on cosmology and watch the young people in the audience, and even though they may not understand the details initially, they see the excitement of scientists figuring out the origins of our universe or what's going on at the limits of the universe. Think about the idea of a gravity wave—that space contains matter of various densities and is so much more complex than we ever imagined. That's very exciting to people who understand it.

With the increasing diversity of the student population in schools, how should science education reach out to minority students?

The problem for minority students is the same as the problem for non-minority students: We often don't share the excitement of science with them in a way that's personally meaningful. I have a childlike belief that people only relate to things that are meaningful to them in a personal way and that people are initially excited only by things that they understand. The key to understanding information is being able to realize that "it has something to do with me." I think that we need to do a much better job of showing all students how science is meaningful to them.

I'll give you an example from a science museum that I visited, the Liberty Science Center near Newark, New Jersey, which is heavily minority populated. There were 3,000 school-children in the museum that day. I watched the kids look at a swamp exhibit. They stuck their hands in the tank and explored all the hands-on stuff, and one of the docents came over and started explaining what was going on in the swamp. Now, that part of New Jersey is a serious swamp. The kids learned a lot about water quality and about microorganisms, in a context that was personally meaningful. When they have the personally meaningful hands-on experience, that's likely to be much more exciting to them than if you say, "Let me tell you something really exciting that has nothing to do with you."

What's the most important piece of advice you would give K–12 educators about providing their students with a good science education?

Make sure that whatever science content you're teaching, you are also teaching about the scientific enterprise—its methods, limits, benefits, perils, and pitfalls. The biggest gap that adults have in their scientific knowledge is not that they've forgotten the details of DNA; it's rather that they don't know what science is about. Understanding the nature of science is even more important than mastering its details.

Why I Became a Scientist

Laurence Steinberg

Distinguished University Professor of Psychology, Temple University, Philadelphia

My decision to pursue a career in science was mainly influenced by terrific professors at Vassar. I entered college as an English major, intending to become a writer. A freshman-year course in personality psychology changed my direction.

At Vassar, I worked as a research assistant for a professor studying memory. The training I received in my biology, chemistry, and physics classes sharpened my skills. I even volunteered as an assistant in my organic chemistry professor's lab, studying the properties of amber. This research had nothing to do with my career plans, but I loved the excitement of scientific discovery.

After 30 years as a college professor, I have come to believe that the key to inspiring students to pursue careers in science is not making science appear relevant to everyday life but helping students experience the excitement of the research enterprise. Few things are as satisfying as constructing a hypothesis, designing an experiment to test that hypothesis, carrying out the experiment, and discovering whether you were right.

Too much of today's science education focuses on making students memorize bits of information that will be outdated within a few years. Too little emphasizes how to think like a scientist. And there is no substitute for hands-on research experience.

Respond to this Article

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Science Nourishes the Mind and the Soul

by Brian Greene

Nubar Alexanian

Brian Greene teaches physics and mathematics at Columbia University. He is a proponent of string theory, which attempts to unify all the forces of nature into a single framework. He authored *The Fabric of the Cosmos* and *The Elegant Universe*.

"I believe that through its rational evaluation of truth and indifference to personal belief, science transcends religious and political divisions and so does bind us into a greater, more resilient whole."

Brahms Symphony No. 3

Hear the music to which Greene refers, performed by the Chicago Symphony orchestra and conducted by Sir Georg Solti:

"Allegro con brio" Movement of Symphony No. 3 in F Major, Op. 90 by Brahms

All Things Considered, May 30, 2005 · *Note that the Web audio here is a longer version of what was originally broadcast.* One day when I was about 11, walking back to Public School 87 in Manhattan after our class visit to the Hayden Planetarium, I became overwhelmed by a feeling I'd never had before. I was gripped by a hollow, pit-in-the-stomach sense that my life might not matter. I'd learned that our world is a rocky planet, orbiting one star among the 100 billion others in our galaxy, which is but one of hundreds of billions of galaxies scattered throughout the universe. Science had made me feel small.

In the years since, my view of science and the role it can play in society and the world has changed dramatically.

While we are small, my decades of immersion in science convince me this is cause for celebration. From our lonely corner of the cosmos we have used ingenuity and determination to touch the very limits of outer and inner space. We have figured out fundamental laws of physics -- laws that govern how stars shine and light travels, laws that dictate how time elapses and space expands, laws that allow us to peer back to the briefest moment after the universe began.

None of these scientific achievements have told us why we're here or given us the answer to life's meaning -- questions science may never address. But just as our experience playing baseball is enormously richer if we know the rules of the game, the better we understand the universe's rules -- the laws of physics -- the more deeply we can appreciate our lives within it.

I believe this because I've seen it.

I've seen children's eyes light up when I tell them about black holes and the big bang. I've received letters from young soldiers in Iraq telling me how reading popular accounts of relativity and quantum physics has provided them hope that there is something larger, something universal that binds us together.

Which is why I am distressed when I meet students who approach science and math with drudgery. I know it doesn't have to be that way. But when science is presented as a collection of facts that need to memorized, when math is taught as a series of abstract calculations without revealing its power to unravel the mysteries of the universe, it can all seem pointless and boring.

Even more troubling, I've encountered students who've been told they don't have the capacity to grasp math and science.

These are lost opportunities.

I believe we owe our young an education that captures the exhilarating drama of science.

I believe the process of going from confusion to understanding is a precious, even emotional, experience that can be the foundation of self-confidence. I believe that through its rational evaluation of truth and indifference to personal belief, science transcends religious and political divisions and so does bind us into a greater, more resilient whole.

I believe that the wonder of discovery can lift the spirit like Brahms' Third Symphony.

I believe that the breathtaking ideas of science can nourish not only the mind but also the soul.

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