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FORUM

A Forum piece published in the August 2, 2000 issue of Eos, *about the 1999 decision of the Kansas State Board of Education to prohibit the teaching of evolution in Kansas public schools, elicited the following comment and response:*

The Causes of Anti-Science Views

Johnny Wei-Bing Lin recently suggested (*Eos*, August 2, 2000) that the action of the Kansas State Board of Education to exclude questions about evolution by natural selection and "Big Bang" cosmology from required state tests, was driven primarily by the populism of science—the belief that the judgment of everyday men and women in matters deemed scientific is better than that of the trained scientists. In his view, inadequate public science education is only a secondary reason.

Lin and Baylor University theologian Barry Harvey [2000] have argued that science is now under siege by populism, and that the ruling of the Kansas Board is but one example. To combat this populism, he urges a wider dialogue between scientists and historians, philosophers and theologians, so that we understand better the limits of our work and

from touching high-voltage power lines, although unfamiliar with Electromagnetic Theory. They cook over gas burners, receive nourishment from food, and use gunpowder without understanding the chemical reactions involved in the different ways of producing energy.

Religion is based on faith and this holds, to a lesser degree, for economics and politics. In the past, religious populism has challenged the authority of the church and split religion into hundreds of factions. Over time, some religions have accepted science they once opposed—for example, the recent exoneration of Galileo by the Catholic Church. Science has been criticized in the past for the non-scientific ideas espoused by some noted scientists. Since science progresses by test and not by authority, it has easily weathered such comments.

science they do receive often comes from teachers who are not trained in science and lack sufficient equipment for scientific labs and demonstrations. In contrast, many children attend religious schools at least once a week where their beliefs are formed by faith. It is no wonder that students enter colleges and universities with fixed ideas that sometimes conflict with those of science.

For life-long personal and public benefits, people should be taught science from the cradle to the grave. Pseudo-science and anti-science should be countered with vigorous debate. More science teachers should be trained in our colleges and universities. And scientists should allocate more of their time to the education of children and the public.

I see no reason why a public who lives by the Law of Gravitation and enjoys science-based TV and the Internet cannot willingly accept other, equally valid science, if properly taught from an early age.

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Response

I thank R. Stephen White for responding to my *Eos* Forum article and appreciate the opportunity to have a dialogue with him regarding these issues.

He argues that populism is not the primary cause of anti-science thinking. Rather, public sentiment toward science is one of implicit acceptance. Anti-science thinking and

While I certainly agree that science is a powerful way of knowing, I cannot agree with the contention of epistemic privilege. Science, like all systems of knowledge, has strengths and weaknesses. The rise of modern science occurred during the Enlightenment, when optimism in the power of human rationality predominated. As a result, for around two centuries, many have ignored the weaknesses of science as a way of knowing and have focused instead on just its

ter than that of the trained scientists. In his view, inadequate public science education is only a secondary reason.

Lin and Baylor University theologian Barry Harvey [2000] have argued that science is now under siege by populism, and that the ruling of the Kansas Board is but one example. To combat this populism, he urges a wider dialogue between scientists and historians, philosophers and theologians, so that we understand better the limits of our work and discover ways of being more precise and logical. Such discussions may be necessary, but they are not sufficient.

Contrary to Lin's arguments for society's populism of science, the public already observes and accepts—sometimes unconsciously—many basic scientific laws. This is significant evidence that the present resistance to evolution and the Big Bang theory by certain groups can be overcome with a more rigorous scientific curriculum taught in our schools at every grade level.

Science is unique with its own standard for belief that has already endured centuries of dialogue. The claims of science, unlike those of economics, politics, and religion, are based on experiments, tests, and observations that can be repeated by others. If hypotheses, theories, or ideas do not meet such standards, they are modified or replaced, a process that makes science fluid and ever-changing. Also, science is impartial; anyone with the ability and equipment can put it to the test, regardless of ethnicity, gender, or religion.

The apparent trivialization of "technical utility" by Lin and Harvey also bothers me. Technical utility is where most of the public comes in contact with science. Science is visible everywhere in our homes, workplaces, and places of entertainment. Electrical power, motors, electronic communications, and computers, all based on science, are foundations of modern civilization.

People wisely resist jumping from the roof of a two-story building, even though they may be unaware of Newton's Law of Gravitation. They light their homes with electricity and refrain

In the past, religious populism has challenged the authority of the church and split religion into hundreds of factions. Over time, some religions have accepted science they once opposed—for example, the recent exoneration of Galileo by the Catholic Church. Science has been criticized in the past for the non-scientific ideas espoused by some noted scientists. Since science progresses by test and not by authority, it has easily weathered such comments.

Did anti-scientific populism cause the education debacle in Kansas? I think not. The takeover of the Board followed the pattern of conservative religionists of the past decades. Fortunately, scientists and others were able to educate the public and marshal the voters to win the primary elections of both parties. It guarantees that after the general election, at least three of the four new members backing evolution will replace creationists. Then students can again learn and be tested on the great advances made in the many disciplines supporting evolution and the "Big Bang" origin of the universe.

But anti-science beliefs are still held by sizable fractions of the public that believe in astrology, alien abduction, the paranormal, and alternative medicine—beliefs with little or no scientific proof. These could be viewed as examples of scientific populism. Harvey [2000] suggests that populists are skeptical of all claims to knowledge and suspicious of any means of evaluating their merits. He seems to place the blame on science for emphasizing the importance of skepticism. Skepticism is certainly an important role of science that is directed toward ideas both inside and outside of science. Clearly, the above advocates of pseudoscience are not skeptical of their own beliefs. Nor does it seem to bother them that science experiments and tests do not validate their faith. How may scientists help change these views?

All such questions lead back to square one—to the arguments of Kingston and Lanzerotti [2000] and others. From early childhood to high school, and often beyond, children are taught little science. Whatever

Response

I thank R. Stephen White for responding to my *Eos* Forum article and appreciate the opportunity to have a dialogue with him regarding these issues.

He argues that populism is not the primary cause of anti-science thinking. Rather, public sentiment toward science is one of implicit acceptance. Anti-science thinking and actions are cultural anomalies, possibly the result of conservative political activism, religious schooling, or lack of intellectual rigor.

Certainly, I agree that history shows many examples of times when such forces have contributed to the rise of anti-science sentiment. These forces likely had an important role in the specific case of the Kansas Board of Education decision. But these forces do not act in a vacuum.

They are intimately connected with a cultural context, and this context can at times be more important than the forces noted. I suggest that populism plays such a role in framing and sustaining anti-science sentiment, and that the historical record, when examined over the course of not just a few decades, but a century (or more), strongly supports this hypothesis.

Perhaps the difference between White's position and my own is one of emphasis. He focuses on proximate causes—for example, political activism—while I suggest the cultural context—that is, populism—is more important. It seems to me, however, that the difference may run deeper.

My impression from reading White's comment is that his emphasis on the behavior of groups of individuals is motivated by the belief that science is a unique and privileged way of knowing. This privilege is based upon its objectivity, reproducibility, and self-correcting nature. Thus, any reluctance to accept the conclusions of science must be the result of misguided thinking caused by ignorance or irrationality. Because science is "epistemically privileged," people will naturally accede to its authority if they are properly motivated.

While I certainly agree that science is a powerful way of knowing, I cannot agree with the contention of epistemic privilege. Science, like all systems of knowledge, has strengths and weaknesses. The rise of modern science occurred during the Enlightenment, when optimism in the power of human rationality predominated. As a result, for around two centuries, many have ignored the weaknesses of science as a way of knowing and have focused instead on just its strengths. The work by historians and philosophers of science in the past several decades has helped to correct this lopsided view and has provided a view of science that while more nuanced is also richer. The classic starting point for this analysis is Kuhn [1962]. Bauer [1992] presents a brief summary of arguments against the notion of the epistemic privilege of science and offers a constructive and helpful analysis of how that belief has impacted scientific literacy.

If the notion of scientific epistemic privilege is no longer defensible, then on what basis should we build our arguments against anti-science sentiment? Answering that question will require us scientists to expand our vision and enter into dialogue with our colleagues in history, philosophy, and theology, who have already been studying these issues for quite some time. The result will be a response that, I hope, will be more balanced and effective, because it has a more accurate understanding of the role and nature of scientific knowledge.

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Iron Isotopes (cont. from page 173)

environment. An example is the fractionation of C isotopes between CO_2 gas and the bicarbonate ion (HCO_3^-). Even when complete equilibrium is not achieved, as is often the case in nature, such free energy differences can drive isotope fractionation

nature. Therefore, variations in the Fe isotope system may be more analogous to those of C than those of Ca.

The second major question to ask is, Does biological use justify attention?

From a strictly biological perspective, Fe is of interest because it is used in a wider range of biochemical pathways than any other metal. Particularly interesting is that Fe can act as

could generate isotopic signatures useful for detecting ancient life.

Recent Research Results

Natural variations in the isotopic composition of Fe have been determined in a range of terrestrial and lunar igneous rocks, iron meteorites and loesses, as well as in ancient