SCIENCE, SCIENTISM, AND THE ROLE OF THE SCIENCE TEACHER

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AS SCIENCE TEACHERS, this program's graduates should have a deep understanding of science and its nature. Much of this is accomplished through the requirements of a physics degree that introduces teacher candidates and even engages them in the endeavor known as science. Still, knowing the process and products of science, and its nature, is not sufficient for students to be effective educators. One thing that I have learned through my own experiences over 40 plus years of science teaching is that we must try carefully not to inadvertently (or even overtly) foster a view called scientism.

Scientism is, arguably, the mistaken belief that the "hard sciences" like astronomy, biology, chemistry, geology, and physics can provide all the knowledge necessary to obtain a complete grasp of reality – all that is, was, and ever will be. Scientific knowledge – obtained through the empirical (observational and experiential) processes – is seen as vastly superior to any other forms of knowledge such as those derived by philosophy, theology, and even divine revelation. These latter ways of knowing are considered to be subjective and matter worthy only of private interpretation because they are not based on empirical evidence. Precluded from science is the belief in anything that cannot be experienced.

So many participants engaged in the public's irresolvable issues reject any arguments that are rooted in philosophy, theology, religion. Swept away are arguments from natural law, teleology (the study of ends or purposes), ontology (the nature of being), religious belief, and other systems of logic. How often have we seen philosophical, ecclesial, and biblical teachings relating to abortion and infanticide, divorce and remarriage, child abuse and molestation, racism and slavery, value and obligation, moral and ethical conduct, duty and justice, goodness, truth, beauty, justice, and so much more rejected out of hand because these are, supposedly, matters of only personal opinion? It is more common than you think.

This rejection usually takes a particular form, "We KNOW things through science; you merely BELIEVE because of reason or, worse yet, faith. What you BELIEVE is merely a matter of personal opinion. Your OPINION cannot supersede my KNOWLEDGE which is based on evidence." In the world view of those who embrace scientism, scientific claims can be proven via experience, whereas claims based on other ways of knowing are not and cannot be proven. This view is tacitly espoused in universities, in the media, in the entertainment industry, in politics, in the courts, in personal face-to-face arguments, and many other places. Where this view most often has the most significant and most obvious impact is in the rulings of the US Supreme Court.

Now, do not get me wrong. I know, understand, enjoy, and believe in the findings of "hard science." Science has served as the basis of my professional life for the past 40+ years. My concern about scientism is not based on being anti-science. Nothing could be farther from the truth. I bring it up here because scientism is one of several perversions of science that does matter. Let me explain.

Science can be described as both knowledge and the process of obtaining that knowledge about the physical world. Science uses both observation and experimentation involving physical phenomena to make discoveries about the material world drawing conclusions based on evidence and right reason. Scientism marginalizes philosophy, religion, and other ways of knowing about the natural world.

While the view of scientism is rarely directly espoused in educational circles in my experience, it is there by implication. Science is often presented as the ONLY way of knowing, neglecting other ways of knowing with which science does not concern itself. As a result, students fail to see that a deeper understanding of our universe can be had by going beyond what science and scientists tell us. This extension of science is no mere "random leap of faith."

Science, being limited to phenomenal reality (the material world), cannot shed light, prove, or disprove the existence of numinal reality (the spiritual world). Indeed, those who embrace science to the exclusion of other ways of knowing will not even consider things outside of phenomenal reality. To these individuals, science becomes an obstacle to any non-physical truth that might undergird reality. Yes, scientists seek truth but will never discover it in its entirety if they out-of-hand preclude consideration of anything outside of the universe of observable phenomena.

As "consumers" of science, we must be ever mindful that there are spiritual matters that science cannot address and moral issues that science cannot resolve. Science, being restricted to the physical realm, cannot distinguish between right and wrong, good and bad, virtue, and vice. It cannot tell us which of the following is the most important: the rights to life, liberty, the pursuit of happiness, privacy, and ownership. Neither can science tell us what right to privacy or right to material property actually means. It cannot tell us if corporations have political rights on par with humans. It cannot tell us if or why humans have a particular dignity above other living creatures, and what this dignity implies. Those who embrace scientism do not – indeed cannot – answer these questions on the basis of only empirical evidence. These matters deal with non-material things, things which science does not address.

Those who embrace scientism – be they scientists or non-scientists – are limited in other ways too, even as relates to physical reality. They seem not to understand that scientists cannot see beyond the Big Bang to its cause, fathom the origin of life, and find the source of self-awareness. They cannot explain how inert matter gives rise to consciousness. They cannot explain the natural laws that appear to be written in the hearts of humans. They cannot explain from where a sense of guilt arises. They seem not to understand that life only comes from life, that something cannot come from nothing, and that inexplicable physical laws might be manifestations of an unseen universal will.

No, the conclusions drawn by reasonable applications of faith are not scientific because, as such, they cannot be tested. That is a prerequisite for any scientific claim. Any claim in order to be scientific (not necessarily true) must be falsifiable at the very least. This is so because science is naturally limited only to speaking about the natural world. Science cannot rule whether or not God exists; science cannot determine how many angels can dance on the head of a pin; science cannot prove that its claims based on faith are not reasonable or unreasonable. Anyone who uncritically swallows statements of scientists in relation to these matters is swallowing scientism hook, line, and sinker. They are deluding themselves.

Scientism matters. It matters because it calls for the rejection of explanations based on evidence and right reason that might be worthy of consideration. Scientism has led many to dismiss out of hand belief in the spiritual world that evidence and right reason seem to suggest. Many, at least in my experience, have sought refuge in agnosticism and atheism as a result of scientism. This does matter because scientism has led to increasing hostility toward religious and other beliefs in all their forms.

DO NOT SCIENTISTS ALSO BELIEVE?

To assume that scientists deal only with knowledge and not beliefs is absurd. Scientists cling to plenty of beliefs; they often call these beliefs assumptions or postulates to avoid appeals to authority. Still, in making such proclamations, they make themselves the authority. For instance, consider the following claims made by scientists:

- Nature is the same everywhere; all laws of science are universal and not merely local.
- The natural processes in operation today can explain physical events – past, present, and future.
- No observed effect exists without a natural cause.
- Sequence – no matter how frequently repeated – does not necessarily infer cause and effect.
- The universe is understandable and predictable, based on physical phenomena alone.
- Scientists do not accept any kind of explanation for which no test is available or possible.
- When there are two or more possible explanations, the simpler is to be preferred (Occam's razor).

The work of scientists that goes beyond mere reason is often most highly rewarded. These "flashes of insight" are what distinguish the collectors and recorders of scientific data from creators of so-called scientific knowledge. As Jacob Bronowski noted, scientists are not "cameras" merely set on recording information and gathering it into tables. Unless they go beyond what the data say and draw conclusions from the evidence, they are not scientists. "The data suggests X" is the hallmark of the true scientist. Making sense of data is what science is all about. When one makes a "leap of faith" to conclude what the data suggests, then one is doing science.

PHYSICS AND ITS RELIANCE UPON FAITH

One good example of the existence of "scientific faith" is in the statement, "All copper conducts electrons." How do we know this, or do we merely believe? This conclusion is based on an inductive process, which is not a scientific process. Even if one tests 1,000 samples of copper to see if each conducts electricity, how does one know that the next one will not be the sample that does not lead to the same conclusion? One does not, and one cannot. A positive statement like the one in question can never be proven, only disproven. Every sample of copper in the universe would have to be tested for the claim to be proven. Only one non-conducting sample of copper would be adequate to disprove the rule.

How do scientists know that "all copper conducts electricity" is a true statement – something consistent with reality? The fact of the matter is that they don't; they merely believe. The conclusion is not valid based entirely on empirical evidence. Faith plays of a significant role in the acceptance of the claim.

Now, consider a scientist studying the relationship of force, mass, and acceleration in a laboratory setting. Following a set of experiments that show $a \propto F$ and $a \propto 1/m$, a graph is made of F versus ma. The graph best fits the linear relationship $F = kma + b$. The slope, k, is found to be, say, 0.9798, and the constant b is found to equal $0.0321N$. The conclusion based solely on evidence is that $F = 0.9798ma + 0.0321N$. Now, this conclusion is preposterous. For instance, if $a = 0$, then $F = 0.0321N$. The "real" scientist sees beyond the data – makes a leap of faith – and states $F = ma$, realizing that the difference between evidence and conclusion are due to errors in measurement.

The belief that $F = ma$ is a statement of faith that goes beyond what the evidence suggests. Still, this faith is not entirely unfounded. The statement $F = ma$ is an example of the perfection of reason. As St. Augustine said, “Faith is the perfection of reason.” Is this now what we are seeing in the present case? Are we not seeing a practical example of faith?

Of course, science is more than merely an attempt to develop general principles and specific laws based on empirical evidence. It is also an effort to explain certain relationships between and among observed evidence. As such, science also is geared toward the abductive processes of hypothesis and theory development. These practices include good doses of evidence and the use of rational thought but go far beyond principle and law development to come up with explanations.

An experience that lucky undergraduate physics majors have is conducting hypothesis development in an effort to determine the origins of the buoyant force. While the hypothesis that the difference in forces between the top and bottom surfaces of an immersed object does not admit other assumptions such as “and then a miracle occurs,” the hypothesis can readily be tested and indeed proven. This is not always so with physics. Consider, for instance, questions about the nature of the Standard Model of the atom, the existence of dark matter and dark energy, and the origin of the universe with a cosmic Big Bang.

Through the use of powerful colliders such as those at Fermilab and CERN, physicists have come to believe that the nucleus consists of subatomic particles which, by the standard model, themselves consist of different combinations of numbers and types of quarks. No one has ever seen a quark or isolated a quark. They are only hypothesized to exist – and then only in groups of two or three under the current conditions of the universe. The reason that scientists accept the standard model of the nucleus is because it works. It both explains and predicts accurately. Still, that is no guarantee that it is true. It is just the current best explanation – just like other models before it: the plum pudding model, the Bohr model, the quantum model, and so forth. Scientists believe in something that they cannot see, only deduce from evidence.

Though they cannot see dark matter despite repeated attempts at detecting it, astronomers believe firmly in its existence. Rotation curves of galaxies show beyond any reasonable doubt that most of a galaxy's mass exists beyond its visible disk of stars. This belief in something they cannot be seen or directly detected– merely deduced from existing evidence – is considered by scientists to be a logical extension of what empirical evidence seems to suggest.

Though they cannot account for it, the recently detected increasing rate of expansion of the cosmos that was initiated with a Big Bang some 13.8 billion years ago, astronomers are now claiming the existence of dark energy. The increasing rate of expansion – contrary to everything our knowledge about gravity suggests – indicates the presence of this mysterious dark energy – a mysterious force not unlike gravity but one the grows with increasing distance. Again, belief in the existence of dark energy is seen to be a logical extension of what empirical evidence seems to suggest.

It is interesting to note from these examples that some scientists are doing the same thing they claim others should not do – believe in things for which there is no direct empirical evidence – merely suggestive evidence. When religious believers point to the existence of God as an explanation for the origin of the universe, of life, of consciousness, of guilt, and so much more, are they doing anything

different than what scientists themselves are doing? In all of human experience, we have never seen an effect without a cause, life originating from non-living material, and neither can we explain how complex combinations of elements can produce consciousness, emotions like love and hate, and even guilt. How is it that we are more than the sum of our parts?

May not religious believers likewise use right reason to draw conclusions suggested by the evidence just as scientists do? Is not religious belief in an uncaused cause just as legitimate as a belief about the origin of the universe, the existence of dark energy and dark matter, and so forth? Are scientist guilty of a double standard? Do scientists hold non-scientists to standards that they themselves do not uphold?

MATHEMATICIANS TOO!

Like physicists, mathematicians have faith, too. Consider, for instance, their belief in an infinity of integers – whole numbers – without ever having seen or experienced an infinity of numbers. How do they "know" that infinity exists? They do not. They merely believe. By using rational thought, they conclude that whole numbers exist without limit. The reason that if one states a number, ostensibly the largest number, then one can be added to that number and a larger number than the largest number exists. Therefore, the number of integers exists without limit.

By reason, they also believe in the following relationship:

$$A > B$$
$$B > C$$
$$\therefore A > C$$

Mathematicians believe that A > C without actually having experienced it. Rational thought leads to this conclusion – a belief. Belief is not knowledge, but it can be based upon experience and right reason. Again, the faith of mathematicians is an extension of knowledge – the so-called perfection of reason.

Despite the claim to do otherwise, rationalists (and even experimentalists) say they possess knowledge of things that cannot be seen, cannot be experienced. Like religious believers, they, too, have faith – beliefs based on things other than direct experience.

WHY DO CATS HAVE TAILS?

Scientism arises in part from the fact that humans are proud, and scientists are no exception. Scientists take pride in their work and justifiably so. Today's modern world is a technological marvel. Think about all the time, labor-saving, and entertainment devices with which we surround ourselves. Think of the myriad of toys, computers, TV, microwaves, social communication, and so much that we enjoy and with which we inform ourselves. Think of the advances of the life sciences, earth science, astronomy, chemistry, physics, medicine… All the innovations that make life pleasant, enjoyable, and even fun have mostly been brought about by the findings of science. Scientists and engineers are justifiably proud. Still, this pride must be tempered by reason when it comes to an understanding of the nature of reality. Moreover, while science and its products are indeed amazing, the pride with which scientists view their knowledge of the world, it is neither without limit nor wholly justified.

While scientists seek truth, they should not presume to possess it even when a particular phenomenon is well understood. It was once believed that Newton explained all motion, then along came Einstein and his theories of special and general relativity. It was once believed that the world was deterministic, that if we knew the location and state of motion of every particle in the universe, we could predict the future. This deterministic world view has been replaced by a probabilistic world view based upon the uncertainty of quantum mechanics.

More simply, consider a physicist's knowledge about the flight of a projectile – something that scientists understand well but not entirely. If given initial conditions such as position, velocity, acceleration due to gravity, launch angle, wind resistance, and so forth, a scientist can tell us about the projectile's position, velocity, and acceleration at points of time in the future. Also, if someone wants to launch a projectile like a rocket halfway across the planet, they can do so with uncanny precision!

While it is true that the scientist's knowledge about projectiles is indeed profound, scientists still cannot explain why gravity – which plays a major role in the flight of projectiles – works the way it does. But does knowing the name of something (gravity), or even its magnitude and direction at a particular location ($g = -9.81 m/s^2$), mean that we truly understand what it is and why it operates? Of course not. Saying that when something held up in the air and then released falls to the ground merely notes that it falls and how it falls but does not explain why it falls. Do not confuse knowing the name of something with having any knowledge about it.

This is much like the situation with a stalled car. A car is moving along a highway and then without warning, slows to a halt much to the surprise of the driver. The engine has quit running. While one might know all about thermodynamics, fuel, gas and air mixture, compression, spark plugs, ignition, the stroke of the piston, the turning of the crankshaft, and transfer of mechanical motion through the transmission to the driveshaft and from there to the wheels, this does not mean that the scientist can identify that the real reason behind the car being stalled is that the driver failed to put gasoline into the tank. The reason or reasons – motivation, effort, knowledge – are not physical observables. Therefore the scientist who restricts himself or herself to dealing with physical reality simply does not necessarily have a clue about fundamental reasons that are part and parcel of a true and complete understanding of the nature of the situation.

While a scientist might know that cats have tails, that the tails are long and thin, filled with bones, muscles, tendons, and nerves, are covered with skin and hair, and can be moved in any way that a cat so chooses, this does not mean that scientists know why cats have tails. As Richard Feynman noted, confusing the name for something with knowledge about it is something with which we all must contend.

KNOWLEDGE, REASON, AND FAITH

Science is, in the main, is descriptive and not explanatory. That is, science tends to describe the physical aspects of nature; it can but generally does not explain the reason for nature acting the way it does. Given these facts, it should be obvious that science is limited, and its search for truth destined to end in failure if it does not admit as possible sources of knowledge derived from other ways of knowing. Knowledge, reason, and faith are inextricably linked.

Those who embrace scientism say that the only thing that we can know anything is by experience and that things that cannot be directly sensed cannot be known and therefore, should not be believed. Knowledge and belief are two different things. Knowledge is based upon personal experience; faith might be based upon belief based on trust in something or someone. It also might be based on prior evidence and constitute the perfection of reason. The point is, we must be careful not to reject out of hand other ways of knowing that are not based on science without seriously considering their nature. Is it blind faith in authority, or is it a reasoned conclusion based on evidence? What we sometimes have is well-reasoned faith – the perfection of knowledge rooted in empirical evidence.

THE ROLE OF THE SCIENCE TEACHER

So, what are we as science teachers to make of all these concerns about scientism? In my personal opinion, there are several values and obligations of which teachers of science should aware and hold. I believe that, in relation to science and scientism, three actions are appropriate:

1) We need to know that scientism exists, be fully aware of what it is, and recognize that fact that it manifests in many different ways.
2) We need to understand that the way we teach science can alter student views as they relate to science and scientism.
3) We need to help students to understand the limits of science and that it is not the only way of knowing.

References:

Richard P. Feynman: What is Science?

J. Bronowski: The Creative Aspects of Science

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