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# Learning and Teaching Climate Science: The Perils of Consensus Knowledge Using Agnotology

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**Abstract** Agnotology has been defined in a variety of ways including "the study of ignorance and its cultural production" and "the study of how and why ignorance or misunderstanding exists." More recently, however, it has been posited that agnotology should be used in the teaching of climate change science. But rather than use agnotology to enhance an understanding of the complicated nature of the complex Earth's climate, the particular aim is to dispel alternative viewpoints to the so-called *consensus* science. One-sided presentations of controversial topics have little place in the classroom as they serve only to stifle debate and do not further knowledge and enhance critical thinking. Students must understand not just what is known and why it is known to be true but also what remains unknown and where the limitations on scientific understanding lie. Fact recitation coupled with demonizing any position or person who disagrees with a singularly-derived conclusion has no place in education. Instead, all sides must be covered in highly debatable and important topics such as climate change, because authoritarian science never will have all the answers to such complex problems.

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> "All great truths begin as blasphemies."
> George Bernard Shaw, *Annajanska* (1919)

## 1 Introduction

Agnotology[1] has been defined by Proctor (2008) as the study of ignorance and its cultural production. Proctor sees the study of ignorance as having three facets which result from a basic lack of knowledge (presumably to be ultimately known, if possible), from selective choice (i.e., choosing to remain ignorant), and from an intentional attempt to deceive. With respect to education, all three components are important when studying difficult and/or controversial topics. Science educators must teach what is known and how it has come to be known to be true. But educators must also strive to convey areas where and why scientific knowledge is lacking. Many topics, such as the influence of gravitational fields on stars and orbiting objects or the interaction of particles at subatomic scales are filled with uncertainties because of the very nature of the process involved. Indeed, any complex study will involve ignorance to some degree which must be properly conveyed to students or the general public. But that ignorance resides in an incomplete understanding of the scientific matter at hand, which is different from deliberately and culturally directed ignorance.

How the three facets of agnotological ignorance are treated is therefore of considerable importance. Regarding these three facets, Proctor claims that

> Ignorance has many interesting surrogates and overlaps in myriad ways with—as it is generated by—secrecy, stupidity, apathy, censorship, disinformation, faith, and forgetfulness, all of which are science-twitched…Ignorance is most commonly seen…as something in need of correction, a kind of natural absence or void where knowledge has not yet spread. Educators, of course, are committed to spreading knowledge. But ignorance is more than a void—and not even always a bad thing…A founding principle of liberal states is that omniscience can be dangerous…liberal governments are (supposed to be) barred from knowing everything…juries also are supposed to be kept ignorant, since knowledge can be a form of bias (Proctor 2008, p. 2).

While Proctor sees ignorance as stemming from his list of bad or subversive activities, he also feels it can ultimately be used for good since too much knowledge can create an authoritarian system (i.e., *anti-liberal* in the classic sense of the word) or lead to biases by jumping to erroneous conclusions (e.g., the man who has cried 'wolf' too many times in the past may, in fact, be telling the truth this time around—although ignorance of the past may ultimately lead to an unjustified trust in this individual).

Agnotology also has been defined as "the study of how and why ignorance or misunderstanding exists" (Bedford 2010, p. 159). In this context, agnotology is not limited just to things that are not known but includes those ideas of which we are certain are true but, in reality, are not. Ignorance, or a lack of knowledge, can be used to describe what is not known (i.e., Proctor's First Facet) but the second describes a "willful ignorance" or a condition of "in denial" (i.e., Proctor's Second Facet). The degree that a scientist is certain about something (certainty that is never actually achieved) is because that conclusion is based upon scientific evidence. Unless and until the evidence changes or is supplemented, the scientist has no way of knowing that the conclusion *in reality* is not true, for it is not scientific to reach a conclusion in the absence of evidence. Agnotology is further rooted deeply within a cultural context with humans being the dominant agents of knowledge

[1] "Without knowledge" in Greek would be *agnostos*, so agnostology would be a more accurate term which is related etymologically to *gnosis* and *agnostic*. Here, however, the term "agnotology" will be used to be consistent with Proctor and Schiebinger (2008).

dissemination and concomitant information loss (Schiebinger 2005). Ignorance, in Schiebinger's view, is not simply the product of inexact or uninformed science but arises from cultural, historical, and political biases, both consciously and unconsciously. These three views come together to provide a useful working definition since ignorance arises from both commission[2] and omission and, in its most basic definition, ignorance is simply a lack of knowledge of the truth. This definition of agnotology considers reasons for a lack of understanding or incorrect knowledge and is consistent with that of Proctor (2008) where ignorance arises from such undesirable and likely malicious sources. For the purpose of academic discourse, the word *ignorance* can be used therefore in a vastly expanded manner. Restating and expanding upon Proctor's Three Facets, *Type I Ignorance* represents true ignorance (i.e., a basic lack of knowledge), *Type II Ignorance* represents selective ignorance (i.e., representing an assertion that something is true either without evidence or against existing evidence), and *Type III Ignorance* represents deceptive ignorance (i.e., the willful exercise of cultural bias).

Expanding upon this definition, a focus on *Type I Ignorance* would appear to be a useful teaching tool. It is important to stress what is not known and why just as much as it is to teach what is known and why. McComas et al. (1998) argued that students learn the *what* of science but not the *how* which leads to misunderstandings about how science actually works. Providing an educated discussion of the uncertainties in scientific knowledge is far better than simply proclaiming that "the science is settled" or implying that science provides all the answers. For example, the climate system is exceedingly complex and components of the hydrologic cycle operate on such a large spectrum of spatial and temporal scales that a complete understanding of many processes has not yet been unlocked. Having students comprehend both the depths of scientific knowledge and where and why that knowledge is lacking builds the potential for inquisitive minds that might someday be capable of unlocking these stubborn secrets. At the very least, it provides a true appreciation for the exceedingly complex nature of the world.

It should be noted that agnotology is not the first attempt to classify how human thought goes awry. Philosopher David Stove, for example, attempted to construct a nosology (i.e., a classification of disease) of human thought in 1991. In his essay on *What's Wrong With Our Thoughts?*, Stove argued that

> Defects of empirical knowledge have less to do with the ways we go wrong in philosophy than defects of *character* do: such things as the simple inability to shut up; determination to be thought deep; hunger for power; fear, especially the fear of an indifferent universe…these are among the obvious emotional sources of bad philosophy (Stove 1991, p. 188, italics in original).

Scientists cannot know *why* something is not known or often even that it is not known. Of course, how can something be discussed when scientists do not know that they are ignorant of it! What is important, however, is that scientists be honest and ever-searching for the truth—and on that everyone has to be taken on face-value, assuming there is no hidden agenda or axe to grind.

## 2 Agnotology and Climate Change

Anthropogenic climate change is one of the most controversial and politically-charged topics of recent time. Simply put, the discussion arises from the assertion (hypothesis) that

[2] Indeed, almost every discussion of agnotology and the intent to deceive refers to the 1969 tobacco company memo declaring "Doubt is our product".

dangerous global warming is, or will be, caused by continuing human emissions of greenhouse gases, especially carbon dioxide. This is, in fact, a testable scientific hypothesis. This issue has been viewed as having such significant importance that a special branch of the United Nations, the Intergovernmental Panel on Climate Change (IPCC), has been established to advise governments on the matter.

Consequently, the science of the Earth's climate is a subject that is appropriately broached even in elementary school curricula. But unfortunately, it is one which is very complex. Simplifications must be used to explain topics far more complex than could be breached for the students' level of comprehension. For example, educational materials on climate change are filled with simplistic statements such as "the atmosphere acts like a blanket covering the Earth" or "the Earth's atmosphere functions like a greenhouse, allowing light to enter but inhibiting heat from escaping." These myths pervade because they are simple and students seem to grasp the concept even if they are really being misled. It is well-known that the atmosphere stimulates the transport of energy by convection whereas a blanket warms by inhibiting air motions. Greenhouses warm because the energy exchange by latent and sensible heat is reduced, not because the glass is transparent to light and opaque to infrared (i.e., heat) energy (see Lindzen 2007). Indeed, an experiment was conducted by Wood (1909) where sunlight was passed through both glass (transparent to light but opaque to heat) and rock salt (transparent to both light and heat) with equal warming conditions (see also Jones and Henderson-Sellers 1990).[3] Even in the very use of the word 'heat' there is much confusion (Romer 2001).

But such simplifications teach bad concepts and provide students with a false confidence in their understanding of science that should be, but most often is not, unlearned as they progress to higher levels of study. Although few have heeded his warnings, Essex (1991) proffered an early criticism of such simplistic representations of 'global warming', 'heat radiation', and 'the greenhouse effect' even from a pedagogical sense. Essex concludes that

> The only real certainty is that the definitive questions of prediction (if, how much, when, and where climate change will take place) are fundamental scientific questions that models cannot answer alone. We are *not* faced with a problem that can be treated by mere *applications* of theory imported from *more basic* fields. The problem of long-term prediction is a significant fundamental scientific obstacle even for those other fields that might be appealed to (Essex 1991, p. 132, emphasis in the original).

Overcoming these 'ignorance by commission' statements is a necessary goal to further scientific knowledge; indeed, this goal addresses *Type II Ignorance* (and, in some cases, maybe *Type III Ignorance* issues) and, therefore, should be a desirable goal of true agnotology.

Recently, agnotology has been posited as a viable tool for exploring controversial topics such as global climate change (Oreskes and Conway 2008). But rather than use agnotology to enhance understanding of the complicated nature of a complex system, it has been suggested that agnotology should be used to reinforce one side of the debate. Using anthropogenic climate change as the ideal example, Bedford (2010, p. 161) presents his case as to how the study of misinformation (unintentional) and disinformation (intentional) spread by *skeptic* scientists can be used to teach students the science of global warming and separate it from the "global warming agnogenesis [ignorance] literature." To the degree

[3] We are not arguing here that the 'Greenhouse Effect' does not exist; rather, the Earth's surface is indeed warmer than it would be in the absence of an atmosphere. What Wood's example suggests is that a greenhouse on the Earth's surface warms not because light gets in more easily than heat gets out but because the processes of latent and sensible heat exchange are removed as possible pathways for energy transmission with the outside atmosphere. In the atmosphere, latent and sensible heat fluxes are much more efficient in transmitting heat from the surface to the atmosphere than electromagnetic radiation which is why the greenhouse warms.

that such assertions are true, they apply in spades to the presentations and writings of many scientists who support the IPCC's alarmist view of the situation.

Bedford (2010) concludes that geographic education can be enhanced by an explicit study of agnotology so that critical thinking can be developed, knowledge and comprehension of scientific details can be furthered, and students can better understand scientific literature from newspaper accounts. Indeed, if the study of agnotology can be beneficial to further knowledge and enhance critical thinking, then by all means it should become a part of any educator's toolkit. But our views strongly disagree with Bedford's in that newspaper reports are invariably based on highly-spun press releases and interviews given by those who support the alarmist view and dissenting views, if presented at all, are ridiculed. Thus, as defined by Bedford (2010), agnotology can be used to stifle debate and to require acceptance of a single scientific viewpoint.

Unfortunately, Bedford's view of agnotology in teaching climate change is profoundly misplaced and potentially dangerous. It is based on the notion that dissenting views should not be presented if there is a scientific consensus, even if such a consensus is contrived. Most arguments in support of anthropogenic climate change alarmism assert that climate change has a singular dominant cause—human activities—which has been widely proven and accepted. In such a context, dissention from the supposed consensus is not just ignorant (in the misinformation sense of *Type II Ignorance*) but is also judged to be malicious (i.e., disinformation in the context of *Type III Ignorance*). Indeed, agnotology then becomes little more than an appeal to *attack the opposition*. It is not simply acceptable to teach such a one-sided view of climate change science (nor any other science, for that matter) that amounts to nothing more than the belittlement of opposing viewpoints. This is not how science works, nor what science classrooms should become.

*The science is settled* is a mantra that is often repeated by anthropogenic global warming believers to preclude any further discussion of the science. While an extensive evaluation of the intricacies of climate change science is not provided here, it is important to mention that climate change is an important scientific debate that is far from being well-understood. The interested reader is urged to consult Betz (2009) and Pielke et al. (2009) for a further examination of the true extent of the climate change discussion and the unknowns in climate science; and to the reports of the Non-governmental Panel on Climate Change (NIPCC) for compendious examples of alternative scientific views on global warming to those of the IPCC.[4] The existence of such diverse viewpoints is important for agnotology, since teaching students about the climate *must* include discussions of how complicated the Earth's climate system is and why science cannot possibly, already or ever, have all the answers to every question about climate and its variability and change.

Concomitant with this *attack the opposition* view of agnotology are *ad hominem* attacks on individual scientists as well as a selective appeal to authority and training. The usual mantra of the *consensus* view is to assert that those espousing the consensus are *real* climate scientists whereas *skeptics* are simply commenting on topics out of their field of expertise. It is seldom noted that some of the stalwarts of the *consensus* view were not trained in related fields either or that some of the independent scientists who disagree with the IPCC's alarmist view are highly distinguished. Nevertheless, an appeal to credentials is irrelevant for true scientific discourse. It matters not who funds or conducts the science; what matters is whether the message can withstand scientific scrutiny. Discussion and debate are essential in all areas of scientific discourse, to separate the wheat from the chaff and assertions and hearsay from scientific evidence. At the end of the day, *one plus one*

[4] http://www.nipccreport.org/reports/reports.html.

*equals three* will always be shown to be false, but only if we are willing to listen to a contrasting view that *one plus one only equals two*. It is surely hoped that classroom pedagogy would assert that scientific arguments should be won or lost on the merits of the evidence, not by the pedigree of the people doing the research—and that holds for scientists on all sides of every argument.

Bedford (2010) suggests several outcomes that are to be achieved through the use of agnotology in the global warming debate. The first is to address what is known and why it is known. But put bluntly, this fails to admit that there is any other valid viewpoint except that presented by the 'consensus' authorities, and simply reiterates to students that the science is settled and that science has all the answers. The second outcome stresses the importance of peer review and, in particular, the scientific method. However, it is the third outcome—"Strengthened Critical Thinking Skills"—with which there could not be more disagreement. Bedford states

> A third [outcome] exploits the concept that certain aspects of a multi-faceted problem become less contentious with further research, while new difficulties arise and need to be addressed. It is therefore possible, indeed common, to achieve a scientific consensus on some aspects of a problem, but not others. Thus, for example, there are certainly areas of global warming research that are legitimately contested in the peer-reviewed literature, such as the extent to which hurricanes have already strengthened due to anthropogenic climate change…however, the basics of global warming—that greenhouse gases cause warming, and human emissions of those gases are enhancing the greenhouse effect and causing Earth to warm further—are essentially uncontested. By blurring the distinctions between the generally agreed-upon basics and the still-contested areas at the margins, the agnogenesis campaign is once again able to suggest that there is no consensus on global warming (Bedford 2010, p. 161).

Regarding scientific matters, claims of consensus as an argument for validity are simply noxious. After all the very motto of the Royal Society of London itself is *Nullius in verba*, meaning roughly "Take no one's word for it." Any suggestion that critical thinking is achieved by distinguishing the 'consensus' from other viewpoints is no more than the indoctrination of a single viewpoint. The process of critical thinking requires investigating *all* perspectives analytically, examining their internal consistency, reproducibility (a hallmark of science and scientific inquiry), and coherency from previously-defined set of climate principles. Having a student understand why they should not believe a certain viewpoint can only be achieved by having them analyze that particular viewpoint from all perspectives, not by indoctrinating them that all opposing views are intentional or unintentional misrepresentations of fact. A strengthened understanding of the basic science of weather and climate is truly required because the academic community often substitutes *climate change science* for *climate science*. Indeed, few scientists and educators appreciate how much of climate science is really not known.

## 3 A View of Agnotology and the Classroom

A better approach exists for the use of agnotology in the classroom to foster critical thinking in a healthy atmosphere. First, it has to be noted that students must be provided with a presentation of the basic facts regarding climate science at a level appropriate to their comprehension, before launching into any discussions of mechanisms that might or might not lead to its change and variability. They can only understand climate change if they are first well-grounded in the science of climate, not simply considering it as *average weather*, which is often the way it is presented. Differing viewpoints on this topic must be faithfully and respectfully presented, including a discussion of what is not known or cannot be known. It also is imperative to dispel myths about basic principles that pervade the classroom because of the need for a simplified explanation to a highly complex problem (e.g., the aforementioned "the atmosphere acts like a blanket" example). Students benefit more from open scientific discussions than from a mere insistence to regurgitate facts and figures or even the blind adoption of apparently popular and authoritative claims. Science depends on observational analysis, experimental evidence, rational arguments, and skepticism (McComas et al. 1998). However, McComas et al. (1998, p. 527) are correct when they conclude "it is vital that the science education community provide an accurate view of how science operates."

In 1944, George Bernard Shaw quipped that "the average man can advance not a single reason for thinking that the Earth is round"—the Earth is round simply because scientists say it is. Today, satellites and space flight provide an advantage to demonstrate that the oblate ellipsoid model of the Earth is most plausible. But a student gains far more understanding about the nature of the Earth by asking them to prove to Shaw's "average man of 1944" that the Earth is not flat (i.e., without using pictures from space). Navigation, lunar eclipses, and astronomy all are viable reasons and they provide the student with a better understanding of why we believe what we believe. Thus, learning must include proof of ideas to be truly active learning rather than simply bowing to authority by proclaiming *consensus science*.

This paper begins with an earlier quote from George Bernard Shaw that "All great truths begin as blasphemies." It must be noted that the science has been *settled* many times in past history only to find that the authorities were wrong. The Earth was at the center of the Universe until it was ultimately proven by Johannes Kepler in 1609 that the gravitational model of a heliocentric solar system was correct, in accordance to the suggestions of Nicolaus Copernicus and the observational data of Tycho Brahe. Ignaz Semmelweis suggested in 1848 that hand washing would greatly decrease infant mortality, much to the scorn and ridicule of his peers. It was not until much later that Louis Pasteur and an understanding of germs confirmed that Semmelweis' argument was indeed valid. Continental drift was dismissed as fancy until plate tectonics were better understood in the 1960s, despite the fact that it had been first suggested by Abraham Ortelius in 1596 and developed by Alfred Wegener in 1912.

That is not to say that all of science will one day be demonstrated to be false or that every alternative theory or hypothesis should be considered. Science is constantly evolving; many times scientists get it right, but at the same time many hypotheses are also in time overturned through further knowledge and understanding. Alternative theories also have their merits. Historically, science has been reticent to change paradigms or overthrow existing ideas even when they become demonstrably invalid. Today, funding plays a key role in the professional life of most scientists and funding agencies are unlikely to fund science that challenges existing beliefs, especially if it is likely to cause a politically unwelcome outcome. That is largely because program officers and scientists were once students, and students tend to believe what they were taught.

An example of this was presented in the NOVA program entitled "Do Scientists Cheat?" (NOVA 1988). Amidst the discussion of several prominent university faculty who had committed fraud to garner more funds and to enhance their reputations is the story of Scott McGee who taught biology and the scientific method to seventh graders in Brookline MA (USA). McGee was quoted as saying, "many of us refuse to consider that failure or the discovery that you lack an important piece of information is also valuable information." One of the projects McGee had his students undertake was to fill a large jar with water, algae, microorganisms, mud, and sediments from a nearby pond and observe it for 3 months. The students were then required to write a paper describing what they observed and how it related to the concepts they were learning. Given that ecosystems are exceedingly complex, it is impossible to expect that a jar-sized sample will exhibit all or even any of the basic principles that had been discussed in class. But McGee's seventh graders believed that results are important and reporting that their observations are at odds with the expected theory, developed by authority figures, is not likely to yield a good grade. McGee indicated that all of the eighth graders who had taken his class the previous year admitted they had falsified data to fit the population models they had been taught.

It is uncommon, and not always healthy, for a student to question every fact or theory presented to them. That is why it is imperative that students be taught what is known and why we think it is known to be true, as well as what is not known and why—call that agnotology, if you will. It is further imperative that for controversial topics, such as anthropogenic climate change, other views be presented and discussed. In particular, theories are seldom black-and-white; indeed, the anthropogenic climate change discussion is not polarized into those who believe humans are the only agents of climate change and those who believe humans can have no impact on their environment. Teachers who present only a single viewpoint without a proper discussion of climatic processes, regardless of what that viewpoint is, are only encouraging a generation of students to believe only what they are taught, to portray those with whom they disagree as uninformed or ignorant or biased or deceitful, and to blindly follow authoritarian leadership. Lysenkoism in the Soviet Union from the 1930s through the mid-1960s is a classic example of the isolational utopia that develops when opposing ideas are squelched.

## 4 The Uncertain Nature of Science

Unfortunately, the boundary between what should and should not be questioned in science is fuzzy. It should not be critically presented, for example, that the Earth is flat or that the NASA Moon missions were conducted on a sound stage in the Nevada desert just because someone says it is so. Thus, the need exists to determine guidelines for which scientific topics demand a discussion of multiple interpretations and which ones should be taught as fact—pending credible evidence which may later call them into question. From a strictly scientific point of view, all topics are subject to continuing scientific criticism. Even Newtonian physics has been questioned as to whether it applies at certain space and time scales. But on the education side, it is not useful to present all science as being potentially incorrect, although it is imperative to stress the importance of the scientific method in guiding scientists to know what they believe to be true. So where is the line to be drawn?

Even what is meant by the *scientific method* has changed over the years. Kuhn notes:

> The more carefully [historians] study, say, Aristotelian dynamics, phlogistic chemistry, or caloric thermodynamics, the more certain they feel that those once current views of nature were, as a whole, neither less scientific nor more the product of human idiosyncrasy than those current today. If these out-of-date beliefs are to be called myths, then myths can be produced by the same sorts of methods and held for the same sorts of reasons that now lead to scientific knowledge. If, on the other hand, they are to be called science, then science has included bodies of belief quite incompatible with ones we hold today. Given these alternatives, the historian must choose the latter. Out-of-date theories are not in principle unscientific because they have been discarded. That choice, however, makes it difficult to see scientific development as a process of accretion (Kuhn 2012, pp. 2–3).

Indeed, the common bond that has separated the scientific method (as it has evolved over the years) from mythology has been the empirical evidence. The final arbiter has not been an appeal to authority or consensus or even an argument for the longevity of the theory, hypothesis, etc.; scientific observations have always held the final say. Observational evidence is the key to finding scientific truth. However, results from climate models are often erroneously posited as observations themselves or even data and even when they diverge considerably from the real observations, they are used to drive theory construction. Results from climate models should be used with extreme care and not be taught as scientific fact.

Saloranta (2001) describes the dilemma of policy makers struggling with anthropogenic climate change science. What is the rational approach to policy-making when facts yield an incomplete picture, views of numerous climatologists diverge, and models are inherently uncertain while decision-making, policy makers argue, is critical and urgently pushed by polarized interests? Enter *Post-Normal Science* where stakes are high and conflicting views exist amidst a process filled with a high-degree of uncertainty accompanied by a strong ethics component. Rather than focusing on observational evidence, which may be conflicting and fuzzy, all *stakeholders* (from scientists to lay-people to special interests) contribute to the ultimate decision of what is to be taken as *truth* and subsequently, what should be done with this *knowledge*. It is viewed by adherents as assisting the normal scientific process in areas where the scientific method has failed. Saloranta (2001) makes a strong case as to how the Intergovernmental Panel on Climate Change may have abandoned the traditional, observation-refereed, scientific method in favor of the Post-Normal Science paradigm. However, this new framework places the scientist in the role of an advocate—someone who argues for a particular outcome rather than searching for truth with an unbiased eye. This is anathema to the original definition of the scientific method.

Lackey (2013) highlights this observation by noting that too often scientists have become policy advocates. Rather than being objective, *normative science*—where an assumed and usually unstated policy bias is used to sway the normal scientific process—is a corruption of traditional scientific principles and is rapidly becoming the norm in climate change science. Lackey argues that normative science is stealthy because the advocacy bias is often neither evident nor revealed but usually normative science is filled with qualitative terms that are designed specifically to affect policy, not convey scientific knowledge. Lackey concludes his article by cautioning scientists to play their appropriate role: provide facts, probabilities, and analysis but avoid normative science.

This illustrates precisely why the discussion of anthropogenic climate change must be presented in the classroom as an ongoing scientific debate rather than an authoritative- or consensus-driven fact. The science is indeed uncertain owing to incomplete and complicated observational evidence. Allowing Post-Normal Science to substitute for an observation-based scientific method results in circular reasoning—what a group wishes to be true becomes truth simply because they have deemed it to be. However, students must begin their educational journey by assuming that what they are taught is fact—and that the teacher and/or the textbook are the ultimate authorities. But educators must use this authority with the greatest of care so that students learn about science and so that their scientific knowledge is not undermined by biased presentations from advocates posing as scientists.

## 5 Conclusion

Students are cheated and cannot learn critical thinking if they are only presented with one-sided facts. Presentation of only a consensus viewpoint and the demonization of anyone holding an opposing view in such a complex and unsettled topic as climate change are clearly dangerous to a proper understanding of the science. The limited view of agnotology held by some has represented little more than an effort to stifle debate and to "attack the (presumed) ignorant" through *ad hominem* statements and presentations. One-sided presentations of controversial topics have little place in any academic setting and do nothing to further knowledge and enhance critical thinking. Thus, Chamberlin's (1890) admonishment to circumvent "the dangers of parental affection for a favorite theory" is as valid today as it was in the late 19th Century.

Science education must be such that students can, in fact, argue successfully why they believe what they believe. Understanding what is not known and why must be an essential component of that education. Simple recitation of facts coupled with the demonization of any position or person who disagrees with a singularly-derived conclusion does not develop critical thinking and has no place in education. Students cannot learn the scientific method or critical thinking, nor will they benefit until they have learned to examine all scientific evidence without fear or prejudice. By contrast, a more useful approach is to cover all sides of this scientific debate, recognize that multiple viewpoints (more than two) exist, and stress what is not known and why it is not (call that agnotology, if you will) rather than teaching students that "the science is settled" because authoritarian science has all the answers.

Thus, Weiss (2012, p. 100), who argued that agnotology should "encompass the much more typical realm of genuine uncertainties," is quite correct. Agnotology should not be allowed to devolve into *ad hominem* attacks and motive speculation to further one side of the argument. Science deals with uncertainties—from where they originate, how they affect the results, and how they are considered in reaching the conclusions—and it is imperative that students understand early on that science does not always have all the answers. To truly engage students and make them active learners, a teacher has to present all sides of controversial issues and then teach students how to ascertain consistency, reproducibility, and coherency in their arguments. This is the only way students can actually learn and expand their secure knowledge in scientific subjects. An open mind is the key to true knowledge.

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