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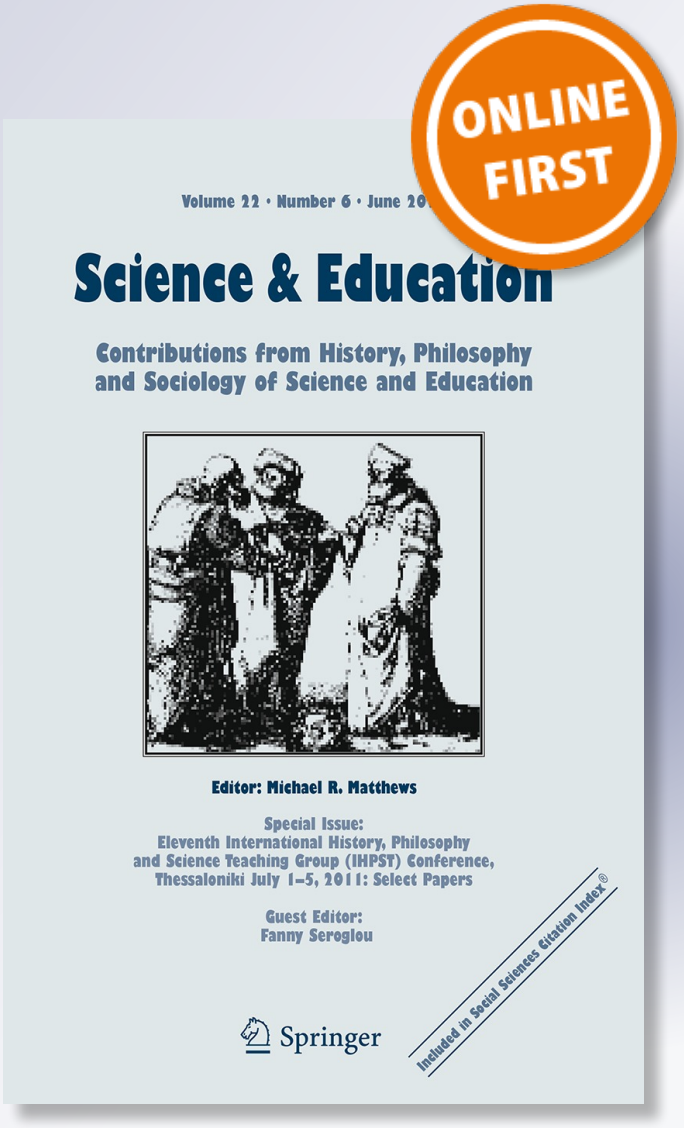
Science & Education
Contributions from History, Philosophy and Sociology of Science and Mathematics

ISSN 0926-7220

Sci & Educ
DOI 10.1007/s11191-013-9608-3



Springer

Sci & Educ
DOI 10.1007/s11191-013-9608-3

Agnotology, Scientific Consensus, and the Teaching and Learning of Climate Change: A Response to Legates, Soon and Briggs

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Abstract Agnotology is a term that has been used to describe the study of ignorance and its cultural production (Proctor in Agnotology: the making and unmaking of ignorance. Stanford University Press, Stanford, 2008). For issues that are contentious in the societal realm, though largely not in the scientific realm, such as human evolution or the broad basics of human-induced climate change, it has been suggested that explicit study of relevant misinformation might be a useful teaching approach (Bedford in J Geogr 109(4):159–165, 2010). Recently, Legates et al. (Sci Educ. doi:10.1007/s11191-013-9588-3, 2013) published an aggressive critique of Bedford's (J Geogr 109(4):159–165, 2010) proposals. However, the critique is based on a comprehensive misinterpretation of Bedford's (J Geogr 109(4):159–165, 2010) paper. Consequently, Legates et al. (Sci Educ. doi:10.1007/s11191-013-9588-3, 2013) address arguments not actually made by Bedford (J Geogr 109(4):159–165, 2010). This article is a response to Legates et al. (Sci Educ. doi:10.1007/s11191-013-9588-3, 2013), and demonstrates their errors of interpretation of Bedford (J Geogr 109(4):159–165, 2010) in several key areas: the scientific consensus on climate change; misinformation and the public perception of the scientific consensus on climate change; and agnotology as a teaching tool. We conclude by arguing that, although no single peer-reviewed publication on climate change, or any other scientific issue, should be accepted without due scrutiny, the existence of a scientific consensus—especially one as overwhelming as exists for human-induced climate change—raises the level of confidence that the overall findings of that consensus are correct.

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Published online: 14 June 2013

1 Introduction

In 2008, science historian Robert Proctor and linguist Iain Boal coined the term "agnotology" to describe the study of ignorance and its cultural production (Proctor 2008). Using a variety of different approaches, both authors of the current paper have examined agnotology in the context of human-induced climate change, comparing findings on the physical science of climate change reported in the peer-reviewed literature with statements made in other forums, such as newspaper columns, or popular books, films and television documentaries. Bedford (2010) suggested using such a comparison to assist in the teaching and learning of the science of climate change, and Cook founded and maintains an extensive and widely referenced website addressing climate change misinformation, SkepticalScience.com, as well as writing extensively on the issue (e.g. Washington and Cook 2011; Farmer and Cook 2013, Chapter 23; Cook et al. 2013).

Recently, Legates et al. (2013) published an aggressive critique of Bedford's (2010) suggestion that dissecting inaccurate material on the physical science of climate change might provide a useful and engaging activity for students. Bedford (2010) argued that allowing students the opportunity to identify where arguments are misleading or contradicted by existing observations, and encouraging them to consider the merits of different publication forums (such as peer-reviewed scientific journal vs. newspaper opinion page), could help to build critical thinking skills and content knowledge. Legates et al.'s (2013) critique of these arguments, however, is based on a comprehensive misinterpretation of the original paper; the unfortunate consequence is that the casual reader, lacking familiarity with the original paper, could easily be left with a thoroughly inaccurate impression of the arguments therein. Post-publication critiques of the peer-reviewed literature are essential to the workings of science, but the critiques must be based on arguments actually made in the original papers if the process is to be constructive.

This article is a response to Legates et al. (2013), and constitutes an attempt to correct the record. We first provide a brief summary of the points made by Bedford (2010), and then examine each point in detail, comparing arguments presented by Bedford (2010), and the evidence to support those arguments, with the critique presented by Legates et al. (2013). This comparison serves to demonstrate how Bedford (2010) was misinterpreted by Legates et al. (2013). Interested readers are, of course, encouraged to examine both papers carefully, to enable their own independent comparison.

2 What Does Bedford (2010) Actually Say?

The basic line of reasoning in Bedford (2010) is as follows. First, there is an overwhelming consensus within the scientific community on several fundamental points regarding human-induced climate change (also known as global warming): the Earth's global average temperature is increasing, and human emissions of greenhouse gases, especially carbon dioxide, are the main cause. Second, despite this very strong consensus, the general public, especially in the United States of America, perceives substantial disagreement among scientists on these fundamentals. Third, a campaign of obfuscation regarding climate change science has been undertaken since the late 1980s, funded in part by the fossil fuels industry; Bedford (2010) identified several studies indicating that this campaign may help explain the gap between the public's perception of the scientific community's views on the issue, and the views of the scientific community itself. Finally, Bedford (2010) suggested that a careful examination of the claims made in popular literature or films

regarding human-induced climate change could be a useful critical thinking exercise and test of content knowledge for students. The emphasis in Bedford (2010) was on examples of persuasive writing in popular forums (such as newspaper opinion columns, and books) that attempted to convince readers that the scientific consensus on climate change is weak or non-existent, and the paper closes with a discussion of the late Michael Crichton's (2004) gripping, but scientifically misleading, novel *State of Fear* as a possible basis for in-class discussion and written assignments. Other avenues for using misinformation in a teaching context were also mentioned, but not discussed in detail. These included misinformation on the consequences of increasing greenhouse gas concentrations, and on the possible consequences of taking action to reduce emissions of greenhouse gases. Although the emphasis in the discussion was on material that misled by minimizing the consequences of human-induced climate change or exaggerating the economic problems that might be caused by limiting greenhouse gas emissions, materials exaggerating the negative consequences of greenhouse gas accumulations were not ignored: the Hollywood blockbuster *The Day After Tomorrow* was named as an example.

There is ample evidence to support Bedford's (2010) line of reasoning, some of which was cited in the original paper and some of which has appeared since publication. Legates et al. (2013) do not provide a substantive rebuttal of this evidence; instead, they mainly refute arguments not actually made by Bedford (2010). Indeed, given this confusion, it is entirely possible that we do not disagree on points of substance, and that the source of the disagreement lies in interpretation problems. A discussion of the evidence for each point, and misinterpretations presented in Legates et al. (2013), now follows.

3 The Scientific Consensus on Climate Change

First, is there a consensus within the scientific community on the basic science of human-induced climate change? Here, as in Bedford (2010) and in most studies on the scientific consensus on this issue, this basic science is defined as the findings that greenhouse gas concentrations have been rising since the Industrial Revolution; this has occurred largely, though not exclusively, due to the burning of fossil fuels; and this increase in greenhouse gas concentrations is the main cause of an observed increase in Earth's global average temperature over the period of instrumental record (generally since the mid-late nineteenth Century). Numerous studies of the scientific literature, and of the views of climate scientists themselves, indicate strong agreement on these basic points: see, for example, Oreskes (2004), Doran and Zimmerman (2009), and Anderegg et al. (2010). In perhaps the most thorough assessment of the peer-reviewed literature on human-induced climate change to date, Cook et al. (2013) examined abstracts for papers published between 1991 and 2011 using the search terms "global warming" and "global climate change" to search the ISI Web of Science database. Of the 4,014 abstracts that expressed a position on the issue of human-induced climate change, Cook et al. (2013) found that over 97 % endorsed the view that the Earth is warming up and human emissions of greenhouse gases are the main cause. Less than 2 % of the abstracts rejected this view. It is statistics such as these that indicate a clear, strong scientific consensus on the basic science. Moreover, the analysis found that overwhelming agreement has been in place since 1991, consistent with other analyses finding a consensus on climate change forming in the early 1990s (Oreskes 2004; Shwed and Bearman 2010). These findings demonstrate that it is possible to find peer-reviewed publications that explicitly reject the scientific consensus on human-induced climate change, but such publications represent a vanishingly small minority of the

scientific community's output on the subject. To cite such publications as evidence that there is substantial disagreement within the scientific community about the fundamental science of climate change therefore misrepresents the state of the science.

Two very important qualifications must be added here, both of which are critical to understanding some of Legates et al.'s (2013) misinterpretations of Bedford (2010). First, the existence and remarkable strength of the scientific consensus on climate change does not, in itself, mean that the consensus is correct; and second, the consensus does not extend to all aspects of the science of human-induced climate change. Oreskes (2004, p. 1686) sums up both points eloquently:

> Politicians, economists, journalists, and others may have the impression of confusion, disagreement, or discord among climate scientists, but that impression is incorrect. The scientific consensus might, of course, be wrong. If the history of science teaches anything, it is humility, and no one can be faulted for failing to act on what is not known… Many details about climate interactions are not well understood, and there are ample grounds for continued research to provide a better basis for understanding climate dynamics. The question of what to do about climate change is also still open. But there is a scientific consensus on the reality of anthropogenic climate change. Climate scientists have repeatedly tried to make this clear. It is time for the rest of us to listen.

Thus, the point being made by citing statistics about the existence and strength of the scientific consensus on human induced climate change is to demonstrate that this consensus is real and strong. Opinion surveys of the American public, in particular, suggest a widespread perception of disagreement among scientists. This perception is inaccurate, and the statistics on the strength of the scientific consensus on climate change are intended to demonstrate this point. The existence of consensus, by itself, does not guarantee that the consensus view is correct, as the quotation above indicates.

Much of the discussion in Bedford (2010) was directed at why the public perception of the scientific consensus on climate change was so divergent from reality—as measured by metrics such as those reported above—and examined approaches of rhetoric presented in newspaper opinion columns and popular books that worked subtly to misrepresent the scientific consensus. It was these materials that Bedford (2010) proposed as potentially useful active learning tools: can students, using their existing content knowledge and critical thinking skills, identify logical fallacies and misrepresentations of the existing state of scientific understanding contained in such works, if they are present? Although Legates et al. (2013) criticize Bedford (2010) for proposing "claims of consensus as an argument for validity" (p. 6), this is not, in fact, proposed by Bedford (2010). Furthermore, to support their critique, Legates et al. (2013) misquote Bedford (2010). Part of a discussion of rhetorical approaches used to mislead consumers of misinformation about the strength of the scientific consensus on climate change is repackaged by Legates et al. (2013) and presented instead as one of Bedford's (2010) suggested learning outcomes from examining misinformation. The original paper (Bedford (2010), p. 161) reads: "A third *approach*…" (emphasis added). Legates et al.'s (2013, p. 6) misquote reads: "A third [*outcome*]…" (emphasis added; square brackets in original). Legates et al.'s misquote fundamentally changes the meaning of the original, which was categorically not a discussion of learning outcomes. Such a discussion does occur, but later in the paper. That discussion is not quoted by Legates et al. (2013).

This misquote relates to the second important qualification about the scientific consensus on climate change mentioned above. That qualification is that the consensus extends to some fundamental points, as noted above and in Bedford (2010, p. 161): "[T]he 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." However, as is made abundantly clear not only in Bedford (2010), but also in numerous other discussions of this issue, there are many aspects of the science of human induced climate change that are still poorly understood and strongly contested within the scientific community. Bedford (2010) provides the example of whether or not hurricane strengths have yet been found to have increased due to rising sea-surface temperatures.

These nuances are not adequately communicated by Legates et al. (2013). Writers and scientists who are unconvinced by the huge weight of evidence that underlies the scientific consensus position on human-induced climate change occasionally argue some variant of the claim that 'the science is not settled' (e.g. Plimer 2009; Lindzen 2009). Sometimes, this is advanced as a response to an alleged assertion by proponents of the scientific consensus on climate change to the contrary—thus, Legates et al. (2013, p. 5), "*The science is settled* is a mantra that is often repeated by anthropogenic global warming believers to preclude any further discussion of the science" (emphasis in original). However, as the discussion above indicates, Bedford (2010) makes abundantly clear that there are areas of uncertainty and debate in the science of human-induced climate change; the earlier quotation from Oreskes (2004) further supports this point. Sweeping claims that 'the science is (or is not) settled' (e.g. Legates et al. 2013, p. 5, p. 9) therefore add little to the discussion, because they miss the point that, for complex, multi-faceted issues such as human-induced climate change, *some aspects* of the science tend to become settled, while other aspects remain or become contentious. Legates et al.'s (2013, p. 9) statement that "The science is indeed uncertain owing to incomplete and complicated observational evidence" is therefore too imprecise to be helpful. To which aspects of the science of human-induced climate change are they referring? Are they proposing that it is unclear whether carbon dioxide is a greenhouse gas? Or that the concentration of carbon dioxide in the atmosphere has increased since direct measurements began in 1958? Or that global average temperatures in 2012 are greater than they were in 1900? If so, it would be intriguing to discover the basis for these claims of uncertainty. While some measure of uncertainty applies to any scientific finding, Legates et al. (2013) appear to be arguing that even these basic points are too uncertain to be taught in a science classroom without some alternative viewpoint to provide 'balance'. An overwhelming body of evidence indicates that this is not the case.

4 Misinformation and the Public Perception of the Scientific Consensus on Climate Change

Bedford's (2010) second and third points address the disconnect between the scientific community's views on human-induced climate change, versus the public perception of those views; and the existence of a deliberate campaign intended to persuade the public that the scientific community is divided on the basic science of this issue. On public perception of the scientific consensus, numerous public opinion surveys have found that a sizeable fraction of the public believes there to be more division among scientists than surveys of the peer-reviewed literature show is really the case. For example, Leiserowitz (2008) and Leiserowitz et al. (2012, 2013) have found between 30 and 40 % of those surveyed believe that there is a lot of disagreement among scientists about whether global warming is even occurring. Higher percentages have been reported in other surveys and research (e.g. Nisbet and Myers 2007; Pew 2012).

Considering the remarkable strength of the scientific consensus on climate change discussed earlier, why does this public misperception persist? One possibility is a

deliberate effort to foster this view among the public. This effort is real, and has been thoroughly documented by Hoggan and Littlemore (2009), Oreskes and Conway (2008, 2010), and Coll (2012), among others, and was reported in the news media by, for example, Wald (1991) and Cushman (1998), both journalists for the *New York Times*. Some examples of findings from this extensive body of research are as follows. McCright and Dunlap (2000) found sharp increases in the number of popular publications attacking the scientific consensus around the time of major international climate change agreements, such as 1997's Kyoto Protocol, suggesting a policy-driven motivation for at least some of these publications. In 1991, the Western Fuels Association conducted a campaign with a primary goal to "reposition global warming as theory (not fact)", using dissenting scientists to construct the impression of ongoing scientific debate (Informed Citizens for the Environment 1991, quoted in Oreskes 2010, p. 138; see also Hoggan and Littlemore 2009). Boykoff (2011, p. 111, pp. 129–131) argues that the news media began to give more time to dissenting views following deliberate efforts to use the news media to contest the scientific consensus beginning in the late 1980s, producing artificially 'balanced' accounts by 1990. An analysis of syndicated opinion pieces by conservative columnists from 2007 to 2010 found the most common climate myth promoted was "there is no scientific consensus" (Elsasser and Dunlap 2012).

Legates et al. (2013) do not seem to dispute the existence of this misinformation campaign; instead, they argue that the origins of, or motivations for, any given piece of writing should not matter; only the substance of the evidence or arguments presented should be evaluated. In principle, we agree with this view. However, the rhetorical techniques employed by some works of misinformation extend to misquoting and gross distortions of source material, and such works have the appearance of attempting to persuade readers, viewers or listeners by fair means or foul. Thus, an awareness that some works are written with a view not to providing accurate reportage but to skewing public perception through misrepresentation becomes important background information. Readers are urged to consult Peterson et al.'s (2008) detailed and rigorous analysis of the myth of the 1970s global cooling consensus for examples of the extent to which misrepresentation can occur. As noted in Bedford (2010), the documentary film The Great Global Warming Swindle (2007) includes footage of oceanographer Carl Wunsch, whose views were so thoroughly misrepresented that Wunsch has stated that the film "comes close to fraud" (as quoted in The Economist 2007).

Knowing that a misinformation campaign exists, and that some purveyors of information can play a little fast and loose with the truth, allows information consumers to be on their guard. This approach has grounding in cognitive research finding that misinformation is less influential if people are warned up front that they are about to receive misleading information (Ecker et al. 2010). While the emphasis in Bedford (2010) was on work that downplayed the importance of human-induced climate change, there was acknowledgement that misinformation could also be provided by those exaggerating the scale of the problem: as mentioned earlier, the Hollywood film *The Day After Tomorrow* was given as an example. Up to a point, then, Bedford (2010) is in limited agreement with Legates et al. (2013), who argued that "To the extent that such assertions [of misrepresentation] are true, they apply in spades to the presentations and writings of many scientists who support the IPCC's alarmist view of the situation" (p. 4–5). Regrettably, Legates et al. (2013) do not elaborate on this view, and provide no examples of the specific scientists or publications that they have in mind, so it is difficult to gauge how far we are in agreement on this point. Indeed, there is much evidence to suggest that rather than present an "alarmist view of the situation", the IPCC is biased towards conservative estimates (Freudenburg and Muselli

2010; Allison et al. 2011; Rahmstorf et al. 2012). Brysse et al. (2013) suggest that this conservatism is due to scientists "erring on the side of least drama".

5 Agnotology as a Teaching Tool

Bedford's (2010) final proposal is that misinformation can be used to provide a potentially useful critical thinking exercise and test of content knowledge for students. Research on the use of misinformation in the classroom is increasingly demonstrating the validity of this approach, as explicit refutation of misinformation in physics (Muller et al. 2008) and psychology classes (Kowalski and Taylor 2009) has been shown to be more effective in dispelling student misconceptions than approaches that do not explicitly refute misconceptions. In addition, a refutational approach dispels a false sense of confidence in misperceptions more effectively than standard lectures (Muller et al. 2008; Muller and Sharma 2012). While it is difficult to demonstrate a causal link between the presence of climate change misinformation in the news media and climate change misconceptions in individuals, it is surely reasonable to utilize some of the more commonly-repeated items of misinformation from the news media as case studies in the classroom setting, for educators utilizing the explicit refutation approach.

Critically important here is the distinction between Bedford's (2010) suggested approach and its representation by Legates et al. (2013). Bedford (2010) explicitly argues for using misinformation from *non-peer reviewed* sources, citing examples from newspaper opinion columns and concluding with a case study of the late Michael Crichton's novel, *State of Fear*. These sources are cited as examples of *misinformation* on climate change. This point seems to have been lost on Legates et al. (2013, p. 5), who state

> Bedford (2010) concludes that geographic education can be enhanced by an explicit study of agnotology…and students can better understand scientific literature from newspaper accounts….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.

Again, they provide no examples or references, so it is difficult to determine whether their characterization of newspaper accounts is accurate (work by Boykoff and Boykoff (2004) and Boykoff (2011) suggests that it is not, arguing that, if anything, newspaper accounts have been biased against the consensus view). However, the critical point is that Bedford (2010) argues for use of *misinformation* from newspaper opinion columns—which, ideally, students will be able to refute—while Legates et al. (2013) seem to oppose the use of newspaper accounts as sources of *information*. The use of newspaper accounts as sources of information on climate change science was not proposed by Bedford (2010).

This error is central to much of Legates et al.'s (2013) critique. They go on to claim "Thus, as defined by Bedford (2010), agnotology can be used to stifle debate and to require acceptance of a single scientific viewpoint" (p. 5). Because the use of misinformation constitutes an explicit call to bring alternative claims about the science of human-induced climate change into the classroom for examination, it is difficult to see how this approach fits Legates et al.'s (2013) characterization of stifling debate. Further, Legates et al. (2013) seem to ignore the idea proposed by Bedford (2010) that useful sources of misinformation can be found in the *non-peer reviewed* literature. The non-peer reviewed literature was emphasized because it is likely beyond the expertise of many undergraduates to make judgments on the technical merits of the peer-reviewed scientific literature in areas of continuing uncertainty in climate change science. Thus, rather than debating the areas that are still widely considered to be areas of uncertainty, Bedford (2010) suggested examining

non-peer reviewed sources that make erroneous claims about the widely agreed-upon basic points of the science on human-induced climate change that we have emphasized throughout this response: carbon dioxide is a greenhouse gas, its concentration in the atmosphere has risen dramatically since the Industrial Revolution, and this has been the main cause of an increase in Earth's global average temperature, observed since the late nineteenth Century. One commonly encountered example is the use of relatively short-term trends to argue that the long-term trend is fictitious or has ended. Thus, Murdock (2008) used a small, very short-term increase in September Arctic sea ice extent—from its then-record minimum in 2007—to argue that concerns over rapidly-diminishing Arctic sea ice cover were overblown; the recent (2012) new record minimum for September Arctic sea ice extent demonstrates that, despite short-term fluctuations, the long-term reduction in sea ice extent continues unabated (see e.g. Walsh and Chapman 2001; Stroeve et al. 2008). Bedford (2010) is very clear that areas of uncertainty and limits to current understanding regarding human-induced climate change exist, and that awareness of these should be communicated to students. Indeed, this really is one of Bedford's (2010) four suggested learning outcomes, unlike Legates et al.'s (2013) misinterpreted learning outcome discussed earlier.

Bedford's (2010) final section outlines a case study of the use of the late Michael Crichton's (2004) novel *State of Fear* in an upper-division college weather and climate class. This is an exciting thriller story, by a phenomenally successful best-selling author, but its portrayal of climate science is deeply misleading. Examination of the claims made in this book about human-induced climate change, and the science of this issue, provides a test of critical thinking skills and content knowledge: can students explain where *State of Fear* gets the science wrong, and, most importantly, support their view with evidence? Thus, although Legates et al. (2013) fear that examination of misinformation in the classroom "becomes little more than an effort to stifle debate and to ''attack the (presumed) ignorant'' through *ad hominem* statements and presentations" (p. 10), the emphasis presented in Bedford (2010) is on evidence-based argument, in which alternative viewpoints on the science of human-induced climate change are explicitly discussed.

6 Conclusion: On the Significance of the Scientific Consensus on Climate Change

In sum, Legates et al. (2013) constitutes a thoroughgoing misinterpretation of the arguments presented by Bedford (2010). This is unfortunate, as there are several points in Legates et al. (2013) with which we agree. For example, we agree that "[a]gnotology should not be allowed to devolve into *ad hominem* attacks and motive speculation to further one side of the argument" (Legates et al. 2013, p. 10). Indeed: any classroom examination of misinformation on climate change should be based on the evidence and arguments presented, and should never become *ad hominem* attacks. However, the broad scope of Legates et al.'s (2013) critique does not accurately represent Bedford's (2010) arguments. We hope that the above discussion has demonstrated the extent to which Legates et al. (2013) misinterprets Bedford (2010). Both papers are readily available to interested readers, and we urge such readers not to take our discussion at face value, but to read the original papers and decide for themselves whether Legates et al. (2013) is an accurate or inaccurate characterization of Bedford (2010).

Beyond these admittedly extensive errors of interpretation, there is a broader issue here, specifically, the nature of the scientific consensus on climate change, and, by extension, the concept of scientific consensus in general. Legates et al. (2013, pp. 7–9) include a

discussion of how ideas that were once dismissed as nonsense by the scientific community have become mainstream, including continental drift and plate tectonics, among others. We agree with their arguments here, as they reiterate basic ideas regarding the workings of science: ideas evolve over time, ideally in response to empirical evidence but, because science is a human endeavor, other less noble considerations occasionally become important, such as egos of individual scientists, or political considerations. Because of this, Legates et al. (2013) argue, research should be scrutinized on the merits of its empirical evidence. Again, we agree.

Where we disagree, however, is with Legates et al.'s (2013) apparent dismissal of the entire concept of scientific consensus. We do not advocate "simply bowing to authority by proclaiming *consensus science*" (Legates et al. 2013, p. 7, emphasis in original), and this position was not taken by Bedford (2010). However, nor do we agree that a scientific consensus is a meaningless concept. Our view is that the processes of peer review and post-publication critique ultimately move human understanding of the universe closer to reality. This movement is not always incremental or linear (see Kuhn 1962); it is, however, mostly (though not always, as discussed above) based on scrutiny of the empirical evidence. Thus, before a research result is published, it must, at least in theory, undergo some measure of scrutiny. Once published, the broader scientific community can scrutinize the work further, and provide critiques and attempts at replication of the results. Thus, while it would be unwise to place too much confidence in any single research result, multiple independently-derived results all pointing towards the same finding provide a much higher degree of confidence that the finding is correct. This is the case with climate change, where a consilience of evidence has been observed that humans are causing global warming (Oreskes 2007).

To be clear, lest our meaning be misinterpreted, this does not mean that individual research results should simply be accepted as truth because they are part of the consensus. As noted by Oreskes (2004, quoted earlier), the consensus could be wrong. Certainly, there may be the temptation for scientists to cheat, as suggested by Legates et al. (2013). However, despite numerous accusations of nefarious behaviour, a number of independent investigations have found no evidence of wrong-doing by climate scientists (Blackman-Woods et al. 2010; Oxburgh 2010; Russell et al. 2010; Foley et al. 2010). On the contrary, there is ample evidence of erroneous research published by scientists working to disprove the scientific consensus on climate change (Benestad et al. 2013).

Detailed examination of the peer reviewed literature, as discussed earlier, suggests that the overwhelming majority of published research supports the scientific consensus that the Earth's global average temperature is increasing, mainly due to the increased concentration of greenhouse gases that has resulted from human burning of fossil fuels since the Industrial Revolution (e.g. Cook et al. 2013). This does not mean that the scientific consensus is indisputably correct—and, of course, as emphasized frequently throughout this paper and elsewhere in the peer reviewed literature, there are many areas of uncertainty and contention remaining in the science of human induced climate change. However, the possibility that thousands of published papers are wrong on the basics is surely vanishingly small.

Several decades of concerted misinformation campaigns targeting the scientific consensus on climate change both necessitates the need to reduce misperceptions and provides educational opportunities. A refutational style of teaching has been shown to achieve conceptual change more effectively than approaches that do not explicitly address misconceptions. This underscores the importance of agnotology as a teaching tool, in which students are empowered to identify misinformation not on the basis of *ad hominem* considerations, but on the basis of the quality of the evidence and arguments presented. By empowering students in this way, we argue that learning of climate science, including

climate change science, and understanding of the nature and processes of science, can be fostered. Agnotology used as a teaching tool thus emphasizes scientific argumentation and critical thinking, surely essential skills for all citizens in the twenty-first century, in which "Comprehending why ideas are wrong matters as much as understanding why other ideas might be right" (Osborne 2010, p. 328).

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