Communicating the Science of Climate Change: A Mutual Challenge for Scientists and Educators

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Abstract

Despite a broad consensus amongst scientific experts that climate change is a serious issue needing the attention of policy communities and the public now, there is considerable public confusion about the related science, and a general apathy about the issue. The confusion about the science can be attributed to a combination of factors, including ineffective communication skills of the scientists involved, misinformation presented by contrarians and the failure of media to distinguish between scientific debate about detail versus significance. Educators and scientists must work together more effectively to address these barriers through improved access to comprehensible and quality information, and to foster a learning environment of critical thinking amongst students studying climate change.

Résumé

Même si les experts scientifiques conviennent en grande partie que les changements climatiques constituent un enjeu sérieux qui nécessite dès maintenant l'attention des décisionnaires et du public, il règne dans le public une grande confusion quant à la science connexe et une apathie généralisée quant à l'enjeu. La confusion relative à la scienc peut être attribuée à une combinaison de facteurs, dont des aptitudes de communication inefficaces chez les scientifiques impliqués, la désinformation présentée par les adeptes de l'opinion opposée et le fait que les médias ne différencient pas le détail de l'importance globale dans les débats scientifiques. Les éducateurs et les scientifiques doivent collaborer de façon plus efficace pour supprimer ces obstacles, en améliorant l'accès à de l'information compréhensible et de qualité ainsi qu'en encourageant un milieu d'apprentissage de la pensée critique parmi les personnes qui étudient les changements climatiques.

Despite decades of related scientific research, public awareness of the possible risks of climate change is relatively recent. The first clear warnings about these risks emerged in October, 1985, when a group of international experts meeting in Villach, Austria warned policy makers that "many important economic and social decisions are being made today on long-term projects . . . based on the assumption that past climate data . . . are a reliable guide to the future. This is no longer a good assumption . . ." (World Meteorological Organization, 1986, p. 1). Three years later, scientific experts, politicians, economists, engineers, environmentalists and others met at the World Conference on Atmospheric Change in Toronto to formally discuss the scientific basis for concern about climate change and suggest possible courses of action to reduce related risks. Participants at that conference agreed that "humanity is conducting an unintended, uncontrolled, globally pervasive experiment [with the Earth's atmosphere] whose ultimate consequences could be second only to a global nuclear war" (World Meteorological Organization, 1988, p. 292). That same year, the UN community demonstrated its concern by establishing the Intergovernmental Panel on Climate Change as a formal mechanism to undertake periodic comprehensive international assessments of the science of climate change and advise appropriate UN bodies of its conclusions.

The Intergovernmental Panel on Climate Change released its first major assessment report in 1990 and a second in 1995. It is currently conducting its third assessment, with expected release in 2001. The key conclusions of the *Intergovernmental Panel on Climate Change Second Assessment Report* suggest a broad concensus amongst scientific experts that changes in climate during the coming century will "probably be greater than any seen in the last 10,000 years" (Intergovernmental Panel on Climate Change, 1996, p. 23), that the related risks of danger to society and ecosystems are real and significant, and that these risks provide rationales for actions beyond "no regrets" (that is, beyond those actions that already make sense for other reasons). Of particular significance was its conclusion, based on evidence about the trends and patterns of recent changes in global climate, that the human influence on global climate already appeared to be discernible (p. 17). The report has been well received within the international atmospheric research community, including the International Council of Scientific Unions, the American Meteorological Society and other prestigious organizations involved in atmospheric research (Avery, Try, Anthes, & Hallgren, 1996). Results from thousands of peer-reviewed research studies published since this assessment have, in general, continued to provide support for these conclusions.

Despite the broad acceptance of the Intergovernmental Panel on Climate Change reports within the science community, numerous media reports imply considerable controversy about the science of climate change. Following the release of its *Second Assessment Report*, various essays and opinion pieces appeared in newspapers that criticized the Intergovernmental Panel on Climate Change process. For example, a *Wall Street Journal* essay by Dr. Frederick Seitz (whose credentials include that of past president of the US National Academy of Science) charged that the final Intergovernmental Panel on Climate Change text had been "cleansed" to "remove hints of the skepticism with which many scientists regard claims that human activities are having a major impact on climate" (Seitz, 1996). Contrarians[1] have also convened meetings and launched websites on the Internet to issue dissenting views, and have circulated petitions to call on policy makers not to take action on climate change (Malakoff, 1998; Pearce, 1997). At the other polarity of opinion, but less vocal, are various environmental groups that have decried the Intergovernmental Panel on Climate Change documents as too cautious, and cloaked in scientific jargon of uncertainty and caveats. They argue that the risks of climate change may be much greater than those presented by the Intergovernmental Panel on Climate Change, and that the policy community is fiddling while the world burns.

Although few of these contrarians appear to have any demonstrable expertise with respect to the science of climate change, their views have received considerable public prominence through extensive coverage by the media. Talk shows and newspaper opinion columns and television documentaries frequently take strong positions allied with those of either the skeptic or the alarmist. Some newspapers invite contrarians to contribute guest columns without providing context or presenting counter-arguments (e.g. Singer, 1999). In fact, responses by experts to correct misleading information are often not published or emasculated by extensive editing (Avery et al., 1996). The consequence of such focus on the controversial aspects of the climate change science, rather than the much broader base of information on which scientists agree, is a public perception of scientific uncertainty that significantly exceeds that perceived within the scientific community itself. It has also contributed substantially to public confusion about what that community can and cannot say about climate change. This provides both scientists and educators with an important responsibility and challenge to more effectively inform society about the science of climate change in a manner that is both credible and comprehensible to the non-scientist. There are substantial barriers to fulfilling this responsibility, but there are also strategies that can help address them.

Understanding Scientific Research and Debate

Scientific investigation or research, properly conducted, is a process by which researchers observe the real world directly or through experimentation, develop theories to explain what was observed, and construct mental or mathematical models based on those hypotheses which can then be tested against the evidence. This iterative process requires frequent refinement of the hypotheses, theories and models that emerge, and careful design of the tests to which they are submitted. It is founded on the concept of "logical thinking," where conclusions must be justified on the basis of verifiable evidence, reasoned arguments and reproducible results. Furthermore, the conclusions are generally assigned a confidence level. Where possible, the confidence levels are quantitative, expressed either as error margins on data or by statistical significance tests that assign a probability of error to the results. The *Concise Oxford Dictionary* simply refers to this process of research as "careful search or inquiry after or for or into," and the "endeavor to discover new or collate old facts" (p. 954).

However, there is another important aspect to this process as it has evolved over the centuries—that of peer-review. Scientists submit their results and conclusions to other experts within their peer community for critical evaluation in an attempt to expose any inappropriate assumptions, flaws, oversights or weaknesses in their methods or arguments. Hence scientific investigation is in essence an adversarial process, with peers playing a "devil's advocate" role to focus debate on what is uncertain rather than what is accepted fact. It is a debate intended to take place within the peer community as a means of vetting the results before they are released to the broader science community, and non-scientific audiences. Hence this vetting process has become an accepted prerequisite for acceptance of the results as a credible contribution to improved understanding. Even then, results continue to be considered "uncertain" if they have not satisfied a critical statistical level of confidence test (usually at the 95% or 99% level). Nor does such vetting exclude future challenges as new evidence emerges. As noted by the scientific philosopher Sir Karl Raimund Popper, "Our belief in any particular natural law cannot have a safer basis than our unsuccessful attempts to refute it" (Popper, 1979, p. 439).

In contrast to the fundamental role of logical thinking in scientific learning, society in general accumulates and processes knowledge through experience, perception and intuition (Kearney, 1994). Thus new information and facts are best understood and assimilated if these are placed within the context of the existing knowledge and past experience of the individual or community. Such learning processes, or acceptance of new information, are seldom based on concepts of uncertainties or proof, but on risks and risk management. That is, uncertainty is simply an accepted aspect of life, and of social and economic behaviour. Hence, public response to perceived risks of danger are usually based on individual and/or collective evaluations of the probability of exposure to danger and the social or economic consequences of such exposure. The risks can then be "managed" by taking actions at the least cost deemed necessary to reduce the risks to acceptable levels. Examples include the purchase of car or home insurance, the improved design of automobiles for safety, and even the wearing of appropriate clothes to cope with inclement weather. Furthermore, the social debate on how to manage such risks normally focuses on seeking consensus between disparate viewpoints, and to minimize conflict through seeking common ground. Thus, the goal is to identify that on which we can agree, and to find mechanisms to mediate disagreement and develop social norms. Hence it is difficult for the non-scientist to grasp the rationale behind the adversarial process inherent in scientific debate, and to understand the insistence on critical thinking, proof and confidence levels in the acceptance of scientific results. This fundamental difference in methods of processing and accepting information presents a formidable communication barrier.

In many respects, the science community is ill-prepared to bridge this communication gap. Its adversarial approach to enhancing knowledge is largely misunderstood by lay audiences, and its focus on logical processes is foreign to much of the general public. Furthermore, its emphasis on internal debate, peer review and on statistical confidence levels makes communicating its results to the public considerably more difficult. Yet, in an increasingly populated and environmentally stressed global community, such information is of paramount importance to decision-makers and the communities they represent.

Given this ineffectiveness and reluctance of the science community to effectively communicate outwards, the voices of those critical of technical assessments prepared by scientists (such as those under the auspices of the Intergovernmental Panel on Climate Change) often receive a disproportionate prominence within the policy and public sectors. Hence it is worth evaluating the role of such critics as science communicators.

Within the climate change debate, contrarians can be broadly categorized into three classifications:

- The *expert*. This contrarian has extensive training within the subject area being debated, is an active participant in related research activities, and publishes papers on the topic within the peer reviewed scientific literature. Challenges and alternative hypotheses and interpretations raised by such individuals within their areas of expertise are, as already discussed, an essential element in the adversarial approach used in scientific investigation and debate. It is by such challenges that significant advancements and corrections can be made in the development of scientific theory and models. Their arguments merit careful attention, but must be considered within the context of the broader background science, much of which is not in dispute. When presented to lay audiences outside of this context, the related information these contrarians provide can be seriously misrepresented or misunderstood.
- The *pseudo-expert*. This critic may have a fair to good background knowledge of the topic area under debate, but has not been directly involved in related scientific investigation. Such critics, while often qualifying as "scientists," are thus commenting on science beyond their own area of expertise or competence. One might compare this situation to that of a medical doctor who specializes in dermatology but expresses his views on the treatment of a possible brain tumor. Their challenges and alternative hypotheses also merit careful consideration, and may be important in cross-discipline debates. However, these critiques do not carry the same weight as that of a qualified expert.
- The *non-expert*. This third group of contrarians includes those who have no scientific expertise to offer, but who use the arguments of others raised within proper scientific debate. Although citing factual information, they often use such information selectively and out of context, and frequently to further their own personal or corporate agendas. Some misuse such information innocently, since they have a fragmented or partial knowledge base. Others may deliberately distort the information and use arguments to discredit the broader science community, much like a defense lawyer might in a court of criminal law. In either case, the information provided often ends up misinforming. Their views and reports are to be used with considerable caution, and within the context of the larger body of scientific information available from the science community.

Bridging the Communications Gap: The Current Status

The international science community already recognized the serious nature of climate change in the early 1970s, and has subsequently devoted considerable effort to improving the understanding of the related science. Following the initial formal warning that emerged from the 1985 Villach meeting, a small group of influential experts convened as an independent Advisory Group on Greenhouse Gases, chaired by Dr. Kenneth Hare (then affiliated with the University of Toronto). The Advisory Group on Greenhouse Gases was to ensure that periodic assessments of the state of scientific understanding were undertaken, and to advise on a possible global convention and other policy instruments needed to deal with climate change. The group helped organize a number of international meetings on the policy implications of climate change in the late 1980s (Agrawala, 1998a).

By 1988, the World Meteorological Organization and the United Nations Environment Programme jointly began the task of establishing the Intergovernmental Panel on Climate Change as a more formal mechanism for science assessments relevant to climate change policy matters. Its mandate was to assess available scientific information on climate change and its environmental and socio-economic impacts, and to formulate appropriate response strategies (Houghton, Jenkins, & Ephraums, 1990). Throughout its subsequent evolution, the Intergovernmental Panel on Climate Change Bureau and plenary body have attempted to keep their activities focused on science assessment, independent of policy debate yet policy relevant. The Intergovernmental Panel on Climate Change has now completed two full comprehensive assessments of the state of climate change related science, has released a number of supplementary special reports focused on specific concerns, and is now in the process of completing its third assessment. To ensure the independence and integrity of the assessments, the preparation of the main chapters of the assessments is led by internationally recognized experts, chosen on the basis of their publications within the peer-reviewed scientific literature. They are assisted by contributing authors who bring specialized expertise to bear. These technical reports undergo a double peer-review process—first by the international community of experts, then after revision a second time by both the expert community and government representatives to the Intergovernmental Panel on Climate Change. The contents of these reports remain the responsibility of the lead authors, and are accepted by the Intergovernmental Panel on Climate Change for information. During the most recent assessment, this process involved more than 1200 scientific experts from a broad range of science disciplines (Agrawala, 1998b).

However, these expert reports are highly technical scientific documents, replete with jargon and complex terminology largely incomprehensible to lay audiences. Hence the Intergovernmental Panel on Climate Change Secretariat, with the assistance of the lead authors of the technical reports, prepares an executive summary to each report that seeks to synthesize its key findings in a more comprehensible manner. This summary is then debated extensively, often word for word, in Intergovernmental Panel on Climate Change plenary meetings to seek consensus from participating representatives of member countries on the final wording of the text. Lead authors of the technical reports attend these debates to ensure that the thrust of their assessments are properly captured. Thus, in theory, the final text has acceptance by the science community and a sense of ownership by the participating countries.

As already noted, the Intergovernmental Panel on Climate Change process has been thoroughly criticized by a number of contrarians (Boehmer-Christiansen, 1996; De Freitas, 1999; Seitz, 1996; Singer, 1998). Some argue that it failed to adequately pay attention to those skeptical of the risks of climate change, or that it has a hidden agenda of stimulating increased funding for science research, not environmental protection. There are also warnings that, in its effort to seek consensus amongst scientists, it stifles the adversarial debates upon which the scientific process is based (Editorial, 1999). Furthermore, the process of simplification from technical report to policy makers summary drops many of the caveats, and hence inadequately retains the context for statements within it (Skolnikoff, 1999). Others claim that it is far too conservative in its conclusions and must seek to make its results more policy relevant (Retallack, 1997; Retallack, 1999). It is also argued that the language of the documents continues to be couched in terms of uncertainties and caveats, rather than in terms of risks more familiar to non-scientific audiences. Hence, the Intergovernmental Panel on Climate Change, while far more effective in advising policy makers than its predecessor, and generally accepted as the most authoritative and credible voice on climate change science, also has its limitations as a means of communicating climate change science to lay audiences.

Many countries also undertake scientific assessments at the national scale. Still reliant on international peer-reviewed literature, such assessments seek to address those aspects of climate change science of particular concern to a nation in greater detail. Such assessments are focused more on the possible climate change scenarios for the region in question, and the implications for impacts on regional ecosystems and socio-economic infrastructures. The process of preparing national assessments further develops domestic expertise that becomes invaluable in advising national policy makers and in contributing to and reviewing the broader international assessments. However, their contents should be considered complementary to, but not as substitutes, for the international assessments.

Comprehensive science assessments, while an important process for assimilating and assessing the quality of available information, are still too detailed and laden with jargon and caveats to be effective mechanisms for communicating information required by policy makers. Integrated assessment models have emerged as one possible tool for resolving this communication barrier (Alcamo, Krieleman, & Leemans, 1996). First developed several decades ago for issues such as acid rain, these models couple socio-economic models to carbon cycle models and climate models, each a simplified representation of the complex models used within the sectoral research communities, to develop more direct linkages between human activities and the impacts of climate change. Such models allow scientists and policy makers to test, in an interactive manner, the impact of alternative policy response options in reducing risks and to examine the implications of scientific uncertainties within the model by including alternative assumptions within the structure of the integrated model. Their results are not policy prescriptive, but do help policy makers to understand some of the complexities of the related risk management challenge (Alcamo et al., 1996; Parry, Carter, & Hulme, 1996; Rotmans & Van Asselt, 1997).

Within a democratic society, however, policy makers are very much influenced and constrained by public opinion. Those who fail to heed public concerns about issues soon lose public office. On the other hand, those who try to implement risk mitigation programs without public support seldom succeed in realizing their goals (Morgan & Dowlatabadi, 1996). Recent opinion polls indicate that, to the Canadian public, climate change is not a major concern. These polls also show that Canadians are not well informed about the risks of climate change, that they do not understand the difference between climate change and other concerns such as ozone depletion, and that they believe that the science about climate change remains very uncertain and inconclusive.

There are three primary mechanisms by which the public (including students) obtains its information on climate change:

- *The public information media*. Journalism is a process of informing audiences by reporting on current events or reporting on topics of interest to the audience. It is the fundamental basis for communications through public media, and the primary means by which the general public receives information. Many journalists undertake careful investigation of the background information and seek to provide balanced assessments of the information they are communicating. However, many of the journalists who cover science stories have no background in science, and there is a serious lack of competent science reporters. Furthermore, journalists, columnists and headline editors often seek to dramatize reports in order to attract the readers' attention and interest. To do so, such reports frequently seek out controversy and dissent by citing contrarians from both polarities of the debate, rather than focusing on the less controversial views of the broader scientific community, or on points of consensus. Likewise some television documentaries and radio talk shows are often crafted as much to entertain as to inform.

As already noted, scientific investigation is an adversarial process where debate is focused on points of disagreement, rather then agreement. That process assumes that the participants already understand the relevant background science, and is appropriate for the development and testing of hypotheses and theories. It also is useful for properly assessing the level of confidence in the available information. However, when the science community assimilates this information for communication to policy makers and the public, the assumption that the audience is cognizant of the context of the debate is no longer applicable, and any points of disagreement must be put into context. At this point, the discussion should focus on what the community can agree upon, and present the points of disagreement in a non-adversarial manner. In fact, continuation of the adversarial spirit can provide incentives to parties to the debate to truncate the information they present in order to support certain arguments, hence inappropriately polarizing the debate and obscuring the collective knowledge available (Pate-Cornell, 1996).

However, despite these concerns, journalists often place scientific debates within public fora where the adversarial aspect of the debate is neither understood nor put into context. This tendency is encouraged both by the ready public access to scientific journals and individual scientists, and the journalistic interest in presenting controversy rather than consensus. Appeals to polarized viewpoints within scientific debates further misrepresents the available information, and often places equal credibility to the views of non-experts, pseudo-experts and experts. Such media reports frequently include incorrect scientific information, or perpetuate incorrect or out-dated perceptions. Even more problematic are the opinion columns in journals that often exclusively represent the polarized views of non-experts.

Hence, while the public media is a vital link in scientific communication to lay audiences, it also contributes to public confusion.

- *The Internet*. With the advent of cyberspace and the Internet, a vast new source of information, including climate change science, has become available to a significant sector of the general public. Most research institutions now include web sites replete with information on climate model results, climate trends, projected impacts of climate change and other valuable data. Research scientists now frequently post their research papers which have been recently published in peer-reviewed science journals on their own individual web sites, and some appear ready to share their data directly with interested users. Hence, cyberspace has become a remarkable source of up-to-date and accurate information, with unprecedented accessibility to lay audiences.

Unfortunately, the Internet has also become the means by which non-experts promote their polarized views or foster the propagation of misinformation to protect vested interests. Such views can relate to both exaggerated claims of pending disaster or denial of any need for concern about climate change. Many of these sites are well designed and attractive to visit, but provide no credentials as to the author's expertise or role, if any, within the research community. Furthermore, while the medical community has now undertaken efforts to provide ethical standards to websites that deal with health issues (Health on the Net Foundation, 2000), there is as yet no such process for developing standards for websites relating to climate change science.

- *The educator*. A recent American survey of high school students suggests that most students are poorly informed on the science of climate change. Much of their information is based on media reports. Yet these students also indicated that they place considerable trust in scientists and educators as a source of information (Adams, 1999; Gowda, Fox, & Magelky, 1997). Since few students have direct access to scientists, this underlines the important role of the educator within formal institutions of learning in communicating the science of climate change.

However, most educators within elementary and secondary schools have limited access to peer-reviewed scientific literature or current science assessment reports. Most rely on course curriculum material and on prescribed textbooks that are often out-of-date with respect to the current science portrayed in media articles and other communication sources. Hence media reports and Internet websites, despite their limitations, become important supplementary sources of information. Improved access to sound and up-to-date science is needed to address these barriers.

Improving the Communication Process through Scientist-Educator Collaboration

The Scientist as Communicator

The adversarial peer review process for debating scientific theories and establishing the confidence level in research results must remain an essential pre-requisite for developing scientific knowledge and understanding. However, to communicate their findings to lay audiences in a manner that is effective and honest, scientists need to assimilate the information into integrated perspectives and move beyond the adversarial processes to focus on communicating the large body of science on which there is agreement (Brown, 1997; Moss, 1995; Vitousek, 1995). They also need to be more pro-active in presenting the information in the context of risks rather than uncertainties, and by appealing to the existing concepts, or cultural models, used by audiences in their daily practices of applying new information to their activities. Furthermore, scientists need to explain to these audiences the relationships between different environmental issues, the linkages between human activities and environmental quality, and the co-benefits of risk management (Lave & Dowlabati, 1993; Kempton, 1997; Metz, 1993; Pielke, 1997).

Unfortunately, scientists are in general poorly trained to do so. One notable exception is the weather forecaster, who must each day process vast quantities of scientific data to develop concise information to users in a context that they can understand and apply to their own circumstances. Such forecasts never use traditional scientific criteria of statistical confidence levels, but present information in terms of risks and probabilities. This information is provided as a public service. In a similar fashion, the climate science community has an obligation to become more engaged in public service, particularly where there are clear indications of risks of danger to society.

There are a number of ways in which such communications can be improved. First, educators within institutions of higher learning, in addition to teaching future scientists in the "scientific method," need to remind students of the responsibilities of the science community within society and train them to communicate science effectively to lay audiences. Some universities now offer such courses, but much more needs to be done to change the culture of the science community. Second, physical scientists need to work more closely with social scientists in order to better relate science research results to societal concerns (Elzinga, 1997; Sanderson, 1997; Von Storch & Stehr, 1997). Third, the science community needs to be more pro-active in working with the public media to ensure that the information conveyed to their audiences is presented with integrity. This will require much more effective use of properly credited web sites to which journalists can turn for information, as well as improved access of journalists to scientific experts. The latter in turn need training on effective interaction with media. Perhaps we also need to explore the option of developing a new discipline of accredited science information brokers who specialize in the assimilation and communication of current science information. Finally, the science community needs to work more closely with the formal educational institutions (Henderson-Sellers, 1998). It is in these institutions where most lay audiences develop their foundational knowledge of science.

The Role of the Educator

In the current educational environment of reduced budgets and increased workloads, educators have a formidable challenge in presenting their students with current and balanced information on environmental issues such as climate change. Information in approved textbooks is usually dated, and time constraints and inadequate access to more current information often limit the opportunities to improve this information base. Yet, as noted, students look to educators and scientists as the most trusted sources of information. If these sources are inadequate, they often turn to media reports and the Internet. This appears to lead to the development of major misconceptions that use judgmental heuristics, confuse weather and climate and lead to "fuzzy environmentalism" (Adams, 1999; Gowda et al., 1997). Because students also contribute to the perspectives and values within the households in which they abide, such misconceptions add to the confusion within the general public about issues such as climate change.

How can the educator deal with these challenges and help correct such misconceptions?

Perhaps the first and most important tool is teaching students the art of discernment and critical thinking when assessing information, and how they can help distinguish between credible and questionable information. For example, when accessing information from the Internet, they need to verify who the authors are, what credentials they have to qualify themselves as experts, whether the information is based on peer-reviewed science, and who is paying for publishing the information. Students can also be engaged in "gaming" exercises or collaborative projects of inquiry and investigation, where various participants seek to represent the perspectives of stakeholders in the debate on the science of climate change. Many educators may already use such techniques, but the recent availability of controversial websites on climate change science make such processes of inquiry and critical thinking more urgent.

Second, the educator can develop closer linkages with scientific experts themselves. While few scientists have the time to visit school classrooms to present information directly, most are quite willing to respond to questions that the educator or his/her students may have. Furthermore, major international science assessment reports are now readily available on the Internet, providing valuable updates to information available in text books.

Conclusions

The science of climate change is complex. It deals with a broad range of scientific disciplines that delve into the processes that control the physics, chemistry and thermodynamics of the atmosphere, the behaviour of the oceans, the ebb and flow of global snow and ice fields, and the dynamics of the global ecosystems. Ultimately, it must address how these components interact and how they respond to forces of change. In other words, it seeks to understand how our planet ticks.

This understanding has become particularly important in the face of evidence that humans are now in the process of interfering with these processes, and that this unintended but relentless geophysical experiment with the Earth's life support system carries with it real risks of significant danger. The international science community has warned policy makers that these risks need to be managed. Yet, to develop the political will and partnerships to respond, society needs to be effectively informed of these risks. Such communications are seriously hampered by a scientific community ill-prepared to interact with social scientists and the general public, by contrarians who, through distorted communications, contribute significantly to public confusion, and by a public more preoccupied by immediate concerns than future issues.

The science and education communities can and should do much more to address these challenges. For the scientist, this means more proactive engagement in dialogue with lay audiences, more interaction with students, and a concerted effort to present information using cognitive processes. Educators, in turn, must seek to become current in the related science through improved access to current and credible information, and they must foster an environment of critical thinking amongst students when confronted with conflicting and confusing scientific arguments.

Notes

[1] For the purpose of this paper, a contrarian is defined as an individual who strongly disagrees with the views or opinions on the risks of climate change held by the broader climate change science community, and hence has a polarized perspective. Thus contrarians include both skeptics and doomsayers.

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