

While it may be policymakers who will set international guidelines for addressing climate change, it is clear that the actions of all individuals in society play a role in the process.

Another aspect of the climate change discussion that creates a need for research-focused curriculum is the presence of debate. Much of what is seen in the media at the time of this writing is news that describes a scientific consensus on anthropogenic climate change. However, there have been skeptic positions taken in very public avenues of discourse, and these can leave the student or non-scientist confused about what is known. Examples of this discourse would be skeptic articles in major newspapers and periodicals; books, at least one of which was mailed to schools in the U. S. and Canada; and the 2008 vice presidential campaign debate, where the issue was raised of whether or not it was important to focus on the reasons for climate change in determining future energy policies. While debate in science is important and expected, our students cannot participate in it without being taught science skills in the classroom.

SCOPE OF WORK

My project is composed of two parts- the examination of educational resources for the topic of climate change, and the application of information from these resources to curriculum design for secondary school students. The goals in this analysis include the following:

- 1.) understanding the main points of the resource authors regarding the nature of climate change
- 2.) analysis of the support for the authors' main points from scientific studies (or scientists) that are cited, and lastly,
- 3.) the application of information from the resources to a curriculum that assists students with meaningful climate change research of their own.

This paper is the means for addressing the information covered in the educational resources that are being compared. I demonstrate the application of the information into curriculum with the presentation of a unit plan for climate change, featuring my own material and that of other educators. The context for the discussion of climate change educational resources is set by first examining the history of climate change, and by also looking at current public opinion on the nature of climate change.

REVIEW OF THE LITERATURE

A Short History of Climate Change Science

Climate change and global warming are terms that are sometimes used synonymously, but they have different meanings in the sense that a ‘warming’ is only one phase of the larger climate system on Earth that naturally features change. Physical evidence on Earth and in space has helped scientists understand that there are many factors that can contribute to the changing of the planet’s climate on a long-term basis. Examples of these factors are solar radiation levels, Earth’s orbit around the sun, volcanic activity, ocean currents, and even plate tectonics. The periods of warming and cooling are referred to as interglacials and glacials, respectively, with the latter being partly characterized by enormous sheets of ice extending from the poles. Recent periods of change within human history include the Medieval Warm Period (A.D.1000-1270) and the Little Ice Age (A. D. 1270-1850) (Singer & Avery, 2007)

The history of climate change discussion among people goes farther back in time than one might think. Weart (2007) notes that climate change was conceptualized in ancient times, with knowledge of the subject growing as the technology to study it improved over time. An important figure in climate science history who warned of possible problems was Guy Stewart Callendar, whose idea of carbon dioxide as a heat trapping agent was indeed borne out by computer climate simulations in the 1970s- “Even subtle changes in the Earth's orbit could make a difference. To the surprise of many, studies of ancient climates showed that astronomical cycles had partly set the

timing of the ice ages. Apparently the climate was so delicately balanced that almost any small perturbation might set off a great shift” (Weart, 2007. Para. 10).

More recently, Earth’s climate has been studied by the Intergovernmental Panel on Climate Change, an organization made up of many scientists who specialize in climate studies. The IPCC has issued four reports over recent years that have studied the connections between human activity and climate change. The most recent report, “Climate Change 2007”, declared that the consensus of the group is that there is 90% certainty that global warming is directly related to human greenhouse gas emissions. The IPCC was awarded with the Nobel Peace Prize for their efforts in raising world-wide attention to this issue.

Public Opinion on Global Warming

Despite the growing body of knowledge about the dynamics of Earth’s climate, and the statements of global warming consensus in the scientific community, there are those who question the “anthropogenic” warming concept. There are also many unanswered questions about climate regardless of which side of the issue one is on.

In a study written by Leiserowitz, (2007), the point is made that people’s understanding of climate change is critical to addressing the issue because it is in the public domain that political pressure emerges. “Public opinion is critical because it is a key component of the socio-political context in which policy makers operate. Public opinion can fundamentally compel or constrain political, economic, and social action to address particular risks. (p. 3) Although there is not a substantial amount of data from which to draw conclusions about American citizens’ perception of climate change risk, various surveys in recent years can inform questions on current thought in the country. In

one of his own surveys, Leiserowitz determined that American concern on climate change was at a moderate level, characterized by the belief that potential changes were more global in nature, but not necessarily local. (Leiserowitz, 2003) This information was supported by a different question that asked Americans to specifically rate the areas of impact as they saw them, locally and globally. In the survey, 68% of the respondents had the highest level of concern for “people all over the world”, and “non-human nature”, while their concern for themselves, their family, and their local community was high for 13% of respondents (p. 14)

While it can be seen from this data that many Americans have accepted the idea that global warming is a contemporary issue of concern, it should also be noted that there are many people who are less certain about it. Perhaps some of the most interesting information from Leiserowitz’s data is the following: while 71% of Americans believe that global warming is happening, only 48% of them believe that there is scientific consensus on the issue of why it is happening, and 40% believe that there is substantial disagreement on the issue. (Leiserowitz, 2007)

A recent poll released by Gallup (April, 2008) reinforces the impression of the public’s stance that we see with Leiserowitz’s work:

Americans do appear to have become more likely to believe global warming's effects are already taking place and that it could represent a threat to their way of life during their lifetimes. But the American public is more worried about a series of other environmental concerns than about global warming, and there has been no consistent upward trend on worry about global warming going back for two decades. Additionally, only a

little more than a third of Americans say that immediate, drastic action is needed in order to maintain life as we know it on the planet (p. 1).

It is likely that there are several reasons for uncertainty in the public mind, among them the presence of skeptic scientists as well as supporters of the theory, deniers with political motivations, and erroneous or misleading reporting in the news media. As I have already described, perhaps the most important issue is the fundamental misunderstanding of important concepts with science in general, and climate change science specifically- due to weaknesses in our educational system.

To fully appreciate the accomplishment of scientific learning, one has to understand the long and painstaking process of acquiring data for testing a hypothesis. This process, along with the along with the all-important skeptic eye, is a part of the realm of science that can become complex. Education therefore needs to not only cover the physical concepts behind climate change, but also the very method in which vast amounts of data are eventually assembled into reliable theories- which may still be questioned.

In the following description of curriculum resources, one can see that climate and climate change are complex topics, and for this reason it is vitally important that students understand the best practices for gathering and analyzing information. They are also topics that can still be found in discussions that feature conflicting viewpoints. This is another important reason that good research skills can help students understand not only this important contemporary issue, but also others that will inevitably surface as well.

Available Educational Resources

Chimes (2007) discusses some of the reasons that teachers face difficulties in addressing the topic of climate change in their classrooms. One of the main points is that currently there are few textbooks that feature it as a subject. This is partly because of the newness of global warming discussion in the secondary education domain. Another issue discussed is the tendency of publishers to avoid controversy.

I was able to find several different types of curriculum for use with secondary school students. The types did include books and textbooks from major publishers, supplementary materials created by professional educator organizations or museums, and also material available on the internet from government websites and independent organizations. Two of the first educational resources on climate science that came to my attention, both directed to my school by outside organizations, took completely opposite positions on the topic. The following analysis of these materials illuminates these positions.

Proponents of Scientific Consensus on Anthropogenic Climate Change

Former Vice President Al Gore's book and film "An Inconvenient Truth" garnered significant attention after its release because of its delivery of the global warming message to a large public audience (2006). The book has an extensive curriculum that accompanies it, designed primarily for high school students. Gore's work lays out the story of climate change by explaining the basic concepts, and then following up with numerous indicators that Gore considers to be evidence of environmental change. This text focuses on quantitative studies, using various patterns in nature to point out the changing environmental conditions of our time. An interesting aspect of this book is that

it has been published at a time when many Americans are still exploring the idea of causes for contemporary climate change.

As with any position taken in the scientific arena, Gore has his skeptics. However, since the book's publication, the IPCC released its fourth and most conclusive report- that humans are very likely causing climate change. Following the publication of the latest the IPCC report, the Academies of Science for the G-8 + 5 Countries (June, 2008) posted official positions regarding scientific consensus on climate change, one example being the 2008 Joint science academies statement:

The national science academies of the G8 nations and Brazil, China, India, Mexico and South Africa have signed a statement on climate change adaptation and the transition to a low carbon society. Adaptation is necessary if the worst impacts of climate change, now and in the future, are to be alleviated. Mitigation and adaptation can complement each other and if pursued together can significantly reduce the risks of climate change impacts. (p. 1)

Skeptics of Consensus on Anthropogenic Climate Change

A teaching resource that represents a skeptical position is the book Unstoppable Global Warming- Every 1,500 Years, by Singer and Avery (2007). Singer, a climate physicist, promotes the idea of a 1, 500 year solar cycle. This idea maintains that Earth's current warming is fundamentally caused by 1,500 year cycles in solar activity, with high periods of energy output causing warmer climates, and lower ones allowing for cooler periods in Earth's history. Singer's most recent book on climate change quotes various studies to support this idea.

One set of specific statistics that is cited comes from a research article by Soon (2005). Soon describes various factors in climate variability, but uses two specific charts to show that temperatures in the Arctic illustrate changes that correlate with solar total irradiance, not levels of carbon dioxide, a greenhouse gas. The authors use this study and the words of another scientist to support their argument.

Wilson (2003) describes a study using satellites that also supports the idea that the sun plays a role. Measurements in this study correlate higher solar output since the 1970s with recent warming. As quoted in this text, Wilson cannot be sure that this is not a short-term trend, because the data does not go back further, but he states that if the higher solar activity has been present over this last century, then it could be “a significant component” of observed warming. In an interview with the senior science writer for Space.com, however, Wilson also states “that does not mean industrial pollution has not been a significant factor” (Para. 8). This statement is not mentioned in the Singer/Avery text.

A second example of an author whose research is presented by Singer and Avery is the late scientist Gerard Bond of Columbia University. According to Singer and Avery, Bond made important contributions to the study of climate change “by analyzing ice-rafted debris in sediments on the floor of the southern North Atlantic Ocean.” (p. 19) This study and others connected to it have provided substantial evidence for a 1,500 year solar cycle that could be a significant factor in climate change. In concluding their description of this work, Singer and Avery state that Bond’s argument is “that the force behind the cycles is solar.” Singer extends this summary by stating that “the more we learn about the 1,500 year cycle, the less likely it seems that the recent warming is man-made- or dangerous.” (p. 28) It is interesting to note then, that Bond referred to concern about

warming in his own description of the study. In an Associated Press news article, Bond described the findings of the study, and then alluded to the idea that human activity could affect the climate simultaneously with natural cycles: "The climate system is extremely sensitive to weak forces, such as solar variability," Bond said. "That should make us that much more worried about greenhouse warming." (p. 1) This is a second example of research summarization in Singer and Avery's discussion that needs explanation, as they state a different conclusion than that of the scientist who was actually involved with the study. This is important since the climate research that is cited is being used as supportive data for the text's central argument.

It is also important, however, to ask whether there are other scientists who question the level of consensus on climate change. For my research purposes, I would ask this question for the following reason: to illustrate that for students, understanding an issue becomes more challenging when there are skeptics, as well as the convinced, who have established careers and credentials in science. I am not attempting to specifically promote either side of the issue with this discussion.

Freeman J. Dyson is a professor of physics emeritus at Princeton University. (Dyson, n. d.) Dyson is an interesting figure in the climate change discussion not because he denies the existence of atmospheric carbon problems, but because he does not see warming as the worst of our environmental concerns. Dyson (n. d.) believes that current computer models are not able to accurately predict future climate conditions regarding temperature, but that our acknowledged carbon increase may cause significant problems with the planet's protective ozone layer. Dyson's prominent position in the scientific community as both a researcher and humanist, in a discipline that is related to climate

change, compel the layperson as well as the academic to consider his points of view.

These views are well-represented in this excerpt from a book review that he wrote for the New York Times. According to Dyson, (2008, Section 2, Para. 14)

Much of the public has come to believe that anyone who is skeptical about the dangers of global warming is an enemy of the environment. The skeptics now have the difficult task of convincing the public that the opposite is true. Many of the skeptics are passionate environmentalists. They are horrified to see the obsession with global warming distracting public attention from what they see as more serious and more immediate dangers to the planet, including problems of nuclear weaponry, environmental degradation, and social injustice. Whether they turn out to be right or wrong, their arguments on these issues deserve to be heard.

For students and teachers of climate change in the classroom, Dyson represents a dialogue that has repeated famously in the history of science, and that can simultaneously leave the non-expert wondering what to think.

A Perspective from Science Educators

For the sake of further perspective, I chose to examine curriculum materials produced by a federally funded educational organization to see how the question of controversy is addressed in materials created by other teachers. The Lawrence Hall of Science's (LHS) Global Systems Science curriculum (Sneider, Golden & Gaylen) is a text for secondary school students produced by the Regents of the University of California. Its sources of support include the National Institute for Global Environmental Change, the National Science Foundation, and the National Aeronautics and Space

Administration. Its contents include chapters ranging from the nature of the Greenhouse Effect, to discussion of the controversy, to what governments are doing about climate change. In particular, in the text's third chapter, entitled "What Is The Controversy About?", the authors address the question of "what is the best explanation for warming in the past 100 years?"(p. 12). This discussion focuses on the two primary causes brought up in the previous texts that I analyzed- solar activity, and human-related carbon emissions. Baliunas of Harvard University's Center for Astrophysics is profiled, and her stated hypothesis is that most of the climate change observed in this century is due to solar activity (p. 18). In fact, Baliunas thinks that as much as 94% of the century's warming may be for this reason (p. 19). It is also noted here that scientists sharply disagree on this point. (p. 19) Global Systems Science cites additional studies that relied on multiple sources (ice cores, mountain glaciers, tree rings, and coral reefs) to illustrate the point that many other researchers are able to find direct correlations between warming and carbon in the atmosphere (p. 19).

The authors' final point on the issue leaves the reader with the understanding that solar activity and greenhouse gases are both likely to be involved with current warming. While there is disagreement on the extent to which each is involved, there are several studies that strengthen the hypothesis that greenhouse gases have "a large impact". (p. 19)

As an educator, I find that the Lawrence Hall of Science text makes a valuable contribution to my goal of designing research curriculum for three reasons. First, the text examines both sides of the debate. The second is that it lists several of the currently unresolved questions, and these can be used to help students acquire climate knowledge

in its own right, while also allowing them to practice sound research skills. Finally, the aforementioned research skills can be used to explore the backgrounds and hypotheses of the researchers who are studying climate change.

For all of these reasons, I believe that research practice in the context of climate change is useful not only for its immediate relevance to students in today's society, but also for the learning tools with which these students are equipped as they then leave this topic for others. As the LHS authors note: "understanding the questions scientists are trying to resolve is, in fact, important for everyone. Our individual actions may be affecting the climate, and climate change may be important to the well being of future generations. In addition, controversy in science provides a fascinating "window" on the nature of science" (p. 13).

Another part of the climate discussion where the importance of critical analysis becomes clear is the debate over the options that our society has for addressing the issue of change. As with all environmental issues, decisions that are made regarding climate change involve the discussion of a cost/benefit analysis.

In general, because of the fact that climate change may impact the ways in which we will choose to produce energy, one finds that opinions range from opposing carbon reductions to dramatically increasing them. One approach to decision making on environmental issues that may affect human health is the precautionary principle. This principle states that it is better to take action on a potentially problematic issue than not, in order to avoid the worst possible scenarios that might result from inaction. According to its proponents, the principle must at times be applied even without complete scientific

certainty on the hazards involved with a particular scenario- the burden of proof being on those who would carry on with the potentially hazardous behavior.

Although this philosophy has its critics, it is mentioned here because according to the United Nations Framework on Climate Change (1992): “The Parties should take precautionary measures to anticipate, prevent or minimize the causes of climate change and mitigate its adverse effects. Where there are threats of serious or irreversible damage, lack of full scientific certainty should not be used as a reason for postponing such measures, taking into account that policies and measures to deal with climate change should be cost-effective so as to ensure global benefits at the lowest possible cost” (Para. 4)

In conducting a unit on climate change research, addressing the question of actions to be taken is important from a pedagogical as well as practical point of view. If students are able to apply what they have learned to the larger societal issues at hand, then they have achieved a higher level of thinking within Bloom’s classification scheme for questions, such as analysis, synthesis, and evaluation. They can approach complex issues. However, students who have studied climate change in particular can also decide what actions, if any, they want to take. The step of using information that they have found for the purpose of forming their own opinions will be used many times in their lives, and as we are seeing today, this process is greatly relevant to the current issues of Earth’s climate change.

Discussion

Summary of Major Findings

In my comparison of curriculum resources, I have found that there is a general consensus of opinion in the scientific community on the nature of global climate change- that it is a function of many natural factors, and that humans are very likely compounding any natural warming at this time. This is most notably reinforced by the positions of not only the International Panel on Climate Change, but also of the Joint academies of the G-8 nations, which includes many of the preeminent organizations for science research in the United States.

I have also found that there is a vocal group of skeptics of the Greenhouse Effect, and they put forth the argument that contemporary climate change is a function of cyclical solar activity, not human activity. Some skeptics are also associated with important institutions in the sciences. There are questions about climate change that are still being researched, and cannot be conclusively answered by scientists at this time. It is for these reasons that students need sound research skills, in order to clarify known facts of climate science, and also areas of further study. Such research skills can also be used by students to comprehend new issues in climate change as our understanding of the phenomenon evolves.

Limitations/Gaps in the Literature

I believe that there is a need for writing that can incorporate the documented need for student research skills with knowledge of an important contemporary environmental science issue- climate change. This combining of curriculums (research methods and climate science) can then help students to not only understand climate change, but also