

Countering Climate Change Denial in the US School System: Approaches and Strategies

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Description of the Problem: Climate Change

Denial in the United States

I. General Overview of Climate Change Denial in the United States

The 2007 Assessment Report of the IPCC declared that now more than ever, global climate change is unequivocal, following a consensus among the science community regarding a massive body of irrefutable evidence (IPCC 2007). In the report produced by Working Group I, climate scientists stress the impacts of human inputs on global climate change, highlighting elevated global atmospheric concentrations of greenhouse gases (GHGs) directly traceable to human outputs. The resulting warming trend over the past 150 years has produced irreversible changes to the environment, including the increase of global ocean temperatures, sea-level rise, decreased global snow and ice cover, increased intensity and irregularity of weather patterns worldwide, and significant changes to terrestrial and aquatic biological systems (IPCC 2007, Working group I: 6-8). In comparison with paleoclimatic recordings gathered from ice-core and tree-ring measurements, climate scientists have concluded that the current changes to the earth's climate are unprecedented in the past millennium. Furthermore, they predict that future changes in the earth's climate will be increasingly severe.

Despite the overwhelming consensus among the international science community as to the severity of global climate change, a significant portion of Americans continue to deny that climate change is happening—or if it is, that it cannot be attributed to human activity. In this portion of the report, we will review the current state of climate change denial¹ in the United States, as evidenced largely through national opinion polls, and some of the predominant arguments against climate science.

¹ In agreement with the National Center for Science Education (NCSE), we believe the term “denial” is appropriate: “Recognizing that no terminological choice is entirely unproblematic, NCSE- in common with a number of scholarly and journalistic observers of the social controversies surrounding climate change- opts to use the terms “climate changer deniers” and “climate change denial” (where “denial” encompasses unwarranted doubt as well as outright rejection). The terms are intended descriptively, not in any pejorative sense, and are used for the sake of brevity and consistency with a well-established usage in the scholarly and journalistic literature. (NCSE 2012: <http://ncse.com/>)

II. Statistics of National Climate Change Denial

Over the past three years a number of surveys have been fielded by the National Survey of American Public Opinion on Climate Change (NSAPOCC), jointly produced by the Gerald Ford School of Public Policy at the University of Michigan and the Muhlenberg College Institute of Public Opinion. These surveys demonstrate an oscillation of public opinion in response to the body of evidence supporting climate change. For example, in response to the question: “is there solid evidence that the average temperature on Earth has been getting warmer over the past four decades?” the percentage of people who responded “yes” varied from 72% in Fall 2008 to only 52% in Spring 2010. By Fall 2011 that percentage had increased to 62%, leading members of the NSAPOCC to produce an optimistically entitled report: “Belief in global warming on the rebound” (Borick & Rabe, 2012).

	Fall 2008	Fall 2009	Spring 2010	Fall 2010	Spring 2011	Fall 2011
Yes	72%	65%	52%	58%	55%	62%
No	17%	20%	36%	26%	32%	26%
Not Sure	11%	15%	13%	16%	12%	12%

NSAPOCC Surveys 2008 -2011

Figure 1. NSAPOCC Survey: “Is there solid evidence that the average temperature on Earth has been getting warmer over the past four decades?” [Source: Borick & Rabe, 2012.]

In a separate series of surveys conducted by the Pew Research Center for the People and the Press a similar skepticism in climate change was observed between 2006 and 2009-- the percentage of respondents who believed there was “solid evidence” that the earth was warming decreased from 77% in 2006 to only 57% in 2009.² Similarly, in response to a question on the severity of the problem of climate change, 43% of the respondents believed global warming was “very serious” in July 2006 — while in October of 2009, that figure dropped to 35%. By November 2011, only 38% of the U.S. population believed climate change was a “very serious” problem.

² [In this report, we use a number of free online resources for the most up-to-date information on polling and other statistics. Additionally we reference data and other information from credible government organizations such as NOAA, IPCC, EPA, etc. While these are often not peer-reviewed sources, we were meticulous in our selection of websites that are considered reputable sources.](#)

"In your view, is global warming a very serious problem, somewhat serious, not too serious, or not a problem?"					
	Very serious	Somewhat serious	Not too serious	Not a problem	Unsure
	%	%	%	%	%
11/9-14/11	38	27	16	17	2
10/13-18/10	32	31	16	18	3
9/30 - 10/4/09	35	30	15	17	3
4/28 - 5/12/09	47	26	11	13	2
4/08	44	29	13	11	3
1/07	45	32	12	8	3
7/06	43	36	11	9	1
6/06	41	33	13	11	2

Figure 2. Pew Research Center Survey: How Serious a Problem is Global Warming? [Source: <http://www.pollingreport.com/enviro.htm>]

III. Counter-arguments of Climate Change Denial:

Among the most common arguments in opposition to climate change are:

- 1) *The climate has changed before.* Therefore, what we are experiencing now is simply a natural fluctuation of the earth's climate.
- 2) *It's the sun.* Climate change is caused not by human activity, but by solar activity, such as the increase of sunspots.
- 3) *It's not a bad thing.* Historically, warm periods have been good for people and the planet, and we will adapt easily.
- 4) *There is no consensus.* Scientists are still divided on the anthropogenic causes of climate change.
- 5) *The evidence is unreliable.* The predictive models and the temperature indicators used by scientists are faulty and untrustworthy.

(Source: Cook, 2012)

Generally, these responses indicate a high rate of doubt and mistrust in the scientific community and their findings. In the aforementioned survey of the NSAPOCC, 81% of individuals who did not believe in climate change agreed with the statement that "scientists are overstating evidence about global warming for their own interests," and 90% believed that "the media is overstating evidence about global warming" (Borick & Rabe, 2012).

Public perceptions of the presentation of evidence about global warming by scientists and the media

Group	Percent of Group that believes Scientists are Overstating Evidence About Global Warming for their Own Interests	Agreement That The Media is Overstating Evidence About Global Warming
Individuals Who Think Global Warming Is Occurring	28%	34%
Individuals Who Think Global Warming Is Not Occurring	81%	90%
Individuals Not Sure About Global Warming Occurring	47%	60%

Figure 3. NSAPOCC Survey: Public perceptions of the presentation of evidence about global warming by scientists and the media. Source: [Borick & Rabe, 2012.]

IV. Origins of Climate Change Denial

Given the amount of irrefutable evidence in support of climate change and the consensus among the scientific community as to its origins and severity, the question remains: Why is climate change skepticism and denial so widespread among the US population? What are the possible origins of this doubt and mistrust, and what are the mechanisms by which it is circulated and inculcated? In response to these questions, it is perhaps helpful to consider the psychological origins of denial, as well as the political and economic interest groups involved in the propagation and spread of climate change denial.

Psychological/ “Way of life”

Some have suggested that the fundamental basis of climate change denial— as a denial of potential threat— is intrinsic to our psychological make-up as human beings (Crompton & Kasser 2009). Humans manage perceived threats towards their existence, well-being, and identity in particular ways, including the employment of strategies to avoid or otherwise reinterpret the threat. Such strategies include:

- 1) *Selective attention.* Limiting one’s exposure to the threat by avoiding information that would cause anxiety.

- 2) *Relativization*. Claiming that the threat is insignificant compared to more pressing challenges, or smaller compared to challenges humans have faced historically.
- 3) *Denial of guilt*. Claiming the problem is not their fault, or that their actions are insignificant compared to those of other processes.
- 4) *Projection*. Similar to denying guilt, this involves projecting guilt onto others or processes outside of human control

(Source: Crompton & Kasser 2009; 17-18).

Each of these strategies listed above is represented in the rhetoric of climate change denial. Since climate change poses a threat to the American “way of life,” individuals and collectivities are apt to approach it with skepticism and dismissal, and to avoid any sense of personal responsibility or blame. By posing counter-arguments such as “the evidence is unreliable” or “there is no consensus,” people are able to dismiss the issue as insignificant and unworthy of attention, thereby limiting their exposure to possible threat and anxiety. In the proposal of alternate explanations, such as “it’s the sun,” or “it’s natural-- the climate has changed before,” the burden of personal and collective responsibility is lifted and projected onto processes outside human control.

It is worthy of noting that resistance to climate change is significantly greater among individuals and collectivities with particular political leanings, as well as those whose livelihoods are more immediately tied to extractive industries of coal and other fossil fuels. This issue will be explored further in the following section.

Political and Economic Factors of Climate Denial

Climate change is a politically charged issue in the United States. As Peter Gleick, CEO of the Pacific Institute, pointedly states:

“When scientific findings have big consequences for policy and politics, anti-science ideology and denial flourish. Religious ideology led the Church to deny Galileo’s scientific findings about the motion of the planets and stars and has fed the continuing denial of evolution in favor of fundamentalist claims of creationism. Stalinist ideology denied the science of genetics and led to a crippling of Soviet agriculture and biology for decades. And a mix of anti-government, pro-fossil fuel, and anti-environmental ideology underlies current denial of human-caused climate change” (Gleick 2011.)

As environmental issues, and climate change in particular, came to the forefront during the late 1980s and early 1990s— with the establishment of the IPCC in 1988 and the United Nations Framework Convention on Climate Change (UNFCCC) at the Rio Earth Summit 1992— politicians in the United States and elsewhere were encouraged to adopt policies of regulation and taxation that were incongruous with the interests of major industries.

Given the alignment of the political right with both pro-industry and anti-government regulation platforms, it is unsurprising that opinions on climate change fall squarely along partisan lines. National surveys confirm that partisan affiliation is strongly associated with individual opinions on climate change: in the NSAPOCC survey, 78% of Democrats agree that there is solid evidence of climate change while only 47% of Republicans are in agreement. Similarly, in a poll conducted by the Center for Climate Change Communication at George Mason University, self-identified members of four distinct politically-affiliated groups—Democrats, Independents, Republicans, and Tea Party members— were asked their opinions on climate change. 78% of democrats believed global warming was occurring, compared to 71% of independents, 53% of republicans, and only 34% of Tea Partiers (Leiserowitz et. al. 2011).

Views on evidence of climate change by selected demographic categories			
	There is Solid Evidence	There is Not Solid Evidence	Not Sure
Democrat	78%	15%	7%
Republican	47%	42%	11%
Independent	55%	30%	15%
White	64%	26%	10%
Non-White	60%	27%	14%
Male	58%	30%	12%
Female	66%	22%	12%
College Degree	60%	27%	13%
No College Degree	66%	24%	11%

NSAPOCC 2011

Figure 4. NSAPOCC Survey: Views on evidence of climate change by selected demographic categories

V. Major players in Climate Change Denial

In response to the rise of attention to climate change in the 1980s and 1990s, a strong conservative backlash arose to launch counter-attacks against the climate science community and to promote doubt in the American public. In 1989, the George C. Marshall Institute, a conservative think-tank based in Washington DC, published an anonymous report endorsed by physicist Frederick Seitz that questioned the scientific consensus on climate change and spurred the creation of the Global Climate Coalition, a collective of business and corporations opposed to climate change (Weart, 2011). Over the next two decades, a growing number of conservative institutions were formed in order to promote climate skepticism and denial in the U.S. population through the distribution of funds and media (Oreskes & Conway 2010). While the Global Climate Coalition was “deactivated” in 2002 after the 2001 IPCC report, a handful of organizations remain and continue to play a strong role in the propagation of climate change denial.

Despite the relatively small number of these organizations, they have a formidable presence in the United States largely due to the fact that their efforts are very well-financed, given their alignment with corporations and business conglomerates. For example, the massive industrial conglomerate Koch Industries (currently ranked by Forbes as the second largest privately held company in the US) is responsible for the creation of the Cato Institute and has contributed major funds over the years towards other conservative think-tanks such as the Competitive Enterprise Institute, the Heritage Foundation, and the Heartland Institute.

While a detailed outline of the initiatives of each of the above organizations will not be covered here, it is worth noting the most recent developments regarding the Heartland Institute’s efforts to alter school curriculum. In early 2012, a leak of Heartland Institute documents (obtained by previously-quoted CEO of the Pacific Institute, Peter Gleick, through regrettable means) revealed that the Institute was channeling \$200,000 into developing an alternative global warming curriculum for K-12 students that would present climate change as a “major scientific controversy,” (Gillis & Kaufman 2012)

While the authenticity of some of the documents was refuted, in February of 2012, the president of Heartland, Joseph Bast, confirmed the curriculum initiative in a video interview with the Wall

Street Journal’s editorial board. As Bast states, the project is designed to address the current “politicized” and “superficial” nature of climate science in K-12 classrooms, and to “bring research and real science into the classroom” instead of presenting it “as just some sort of liberal narrative” (The Wall Street Journal, “The Purloined Climate Papers” 2012). The curriculum is currently in development, though further details about its deployment remain unknown at this time.

VI. Climate Change Denial in the U.S. School System

In 2010, climate change was taught directly in 30 states and indirectly in 12 states, but was still absent from the curriculum in 8 states (Palmer, 2010). Climate change denial first entered the arena of public school curricula in 2008, when Louisiana enacted the “Louisiana Science Education Act,” stating that the State Board of Elementary and Secondary Education must assist teachers in “promot[ing] critical thinking skills, logical analysis, and open and objective discussion of scientific theories being studied including, but not limited to, evolution, the origins of life, *global warming* and human cloning” (See *Appendix A*). This landmark resolution provided the initial framework for the inclusion of climate change denial in public school curriculum, and it has since been replicated in numerous other states.

Texas provides perhaps the most widely publicized case of curriculum revision. Over the past few years, the Texas State Board of Education (SBOE) has implemented education standards that require public school teachers to teach the denial of climate change as a scientifically valid position. Consisting of 15 representatives elected from the various state districts, the Texas Board of Education is responsible for establishing curriculum standards and reviewing textbooks appropriate to those standards. As they write on their website,

“The State Board of Education periodically updates the state’s curriculum standards called the Texas Essential Knowledge and Skills (TEKS). Textbooks and other instructional materials are then written for children based on those standards. More than 48 million textbooks are distributed by the Texas Education Agency to Texas public school students each year.” (Source: <http://www.tea.state.tx.us>).

In the past decade the Texas Board of Education has featured a majority of deeply conservative Republican board members, who have sought to revise curriculum and textbooks to represent a more conservative lens on topics of United States history, sexual education, evolution, climate change, and others. In March 27th, 2009, for example, the SBOE voted to amend language in a

textbook chapter on Environmental Systems to include the phrase: “analyze and evaluate different views on the existence of global warming.” (SBOE Summary of Action Items 3/27/09: <http://www.tea.state.tx.us/index4.aspx?id=5161>). The actions taken by the Texas State Board of Education not only affect Texas, however— since Texas is the second-largest purchaser of textbooks, publishers are often compelled to revise textbooks in order to appeal to board members, and these textbooks are then distributed nationally.

Although Texas and Louisiana have received the most coverage in the media, numerous other states— including Tennessee, Oklahoma, Ohio, South Dakota, Utah, Indiana, Missouri— have also introduced legislation modeled after the Louisiana Science Education Act, effectively encouraging teachers to include climate change denial in their science curriculum. While some of these bills have failed, many of them remain in active discussion. As recently as March 20, 2012 the Tennessee Senate passed a bill, whose critics refer to as “the Monkey Bill,” since it also addresses the teaching of creationism in schools (Humphrey 2012). In fact, in many of these legislation efforts, the instruction of climate change denial is bundled together with evolution. The similarities between climate change and evolution as issues of curricular debate will be discussed in a later section of this report.

VII. Climate Change Denial on the Ground: The Teacher’s Perspective

Even in states where formal measures are not instituted at the state level, teachers still feel tremendous pressure from students, parents, and sometimes even administrators to represent climate skepticism as a scientific position, despite the lack of scientific material to substantiate it. In a national poll by the National Science Teachers Association (NSTA) in late 2011, 82% of teachers have faced skepticism from their students about climate change and climate change education, and 54% have faced similar skepticism from parents.

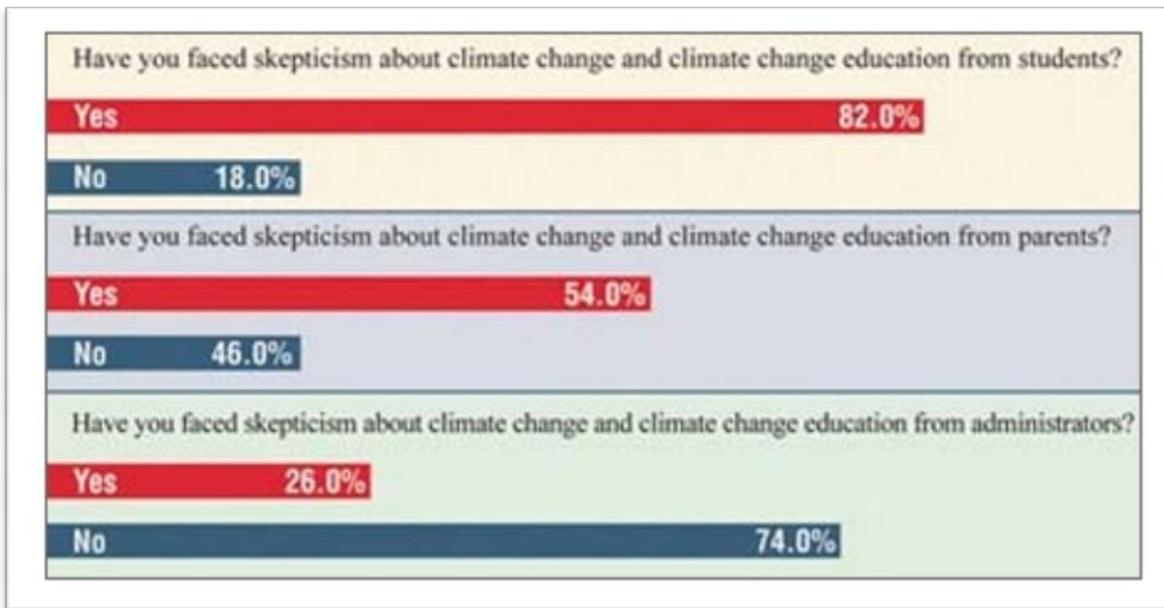


Figure 5: Survey from NSTA: Climate Skepticism 2011[Source: NSTA 11/7/2011]

In further statements from educators, many remark that the issue is clearly a “political” one, and many feel they lack the adequate time and resources to address climate change as thoroughly as possible: as one teacher from Alaska claims, “it is a complex issue that can only be taught if you explore with students the complexities; this takes time and more focused commitment than the typical 50-minute class period allows” (NSTA 2011).

In the above report, educators cited opposition from parents to climate change education as a frequent and frustrating occurrence. In our correspondence with one teacher at a high school in California, he stated that in his 26+ years of high school science teaching, disheartening conversations with parents are “very typical.” He recalls two conversations as particularly disappointing. To quote at length:

The first grew from a perception that the teaching of science should entertain the presentation of all sides of issues... I politely offered that my state standards include concepts built and supported by empirical evidence, and that the general issues involved with global warming were solidly substantiated. The conversations degenerated and became politically polarized in the parents' eyes, and I suggested that if they forwarded me any peer reviewed studies supporting their contentions that I would consider including them in my lectures with my students. One parent did forward me several references, none being published in journals or peer-reviewed. I then emailed the parent a link explaining what 'peer reviewed' journal articles contribute to science dialogs, which apparently insulted the parent, resulting in the parent threatening to contact administration or the school board.

(Personal Communication, 3/28/2012)

In fact, this teacher supported the parent's decision to contact the school board, and even supplied several phone numbers and email addresses. He never heard back from the parents nor received any notification of their contacting the school board.

The constant pressure from parents and students to present "both sides" of a hypothetical climate debate can be an exhausting and disheartening experience, one that no doubt contributes to teacher's fatigue and reluctance to teach rigorous climate science. In a later section of this paper, we will discuss some of the possible tools and training that teachers can access in order to facilitate climate science education and address denial in productive and informative ways.

Analysis:

Evolution and Climate Change Comparison

The issues of evolution and climate change, while not very similar in scientific subject matter, are closely related in the fact that some Americans refuse to believe in either one of them. On the surface, denials of these issues have a few generic similarities: each has a well-funded denial campaign (through conservative think tanks), a champion (Al Gore for climate change and Darwin for evolution), and each issue has been through the political ringer (Morrison, 2011).

Though neither of these scientific facts is inherently political, each has been made into a political issue because of a threat it poses to society. Evolution threatened the religious beliefs that man was made in God's image, while climate change threatens the religious convictions of some, but more importantly, threatens the checkbooks of many because of the necessity of mitigating climate change.³

I. Evolution Background

The main focus of the debate on evolution being taught in public schools is still, almost 100 years later, the Scopes trial. In 1925, John Scopes was tried for violating a Tennessee law against teaching the theory of evolution in public schools. Scopes was found guilty, but was released later on a technicality. This trial was the focus of a national debate between fundamentalist Christians and the science community on evolution, and has produced many years of debate on the same topic (Grabiner, 1974).

After the Scopes trials, teachers began to shy away from teaching any type of evolution in the classroom for fear they would also be put on trial or fired. Textbooks also began to change any sections that were related to the study of evolution. Textbook publishers previously publishing books with sections specifically about evolution removed those sections, while those publishing books that mentioned evolution as a passing thought added more religious undertones to their textbooks to appease the fundamentalist Christian audience (Grabiner, 1974).

³ While conservatism and religious fundamentalism—particularly Christian fundamentalism—are often paired, we wish to be sensitive to the many religious groups that advocate on behalf of climate change, such as Creation Care and other religious environmental organizations.

Though evolutionists thought they had won the battle over public education in 1925, they were mistaken. The battle is, in fact, still waging today. In 1974, the teaching of both evolution and creationism was mandated for elementary school social science curriculum in the state of California (Grabiner, 1974), and official challenges were made as recently as 2004 to the teaching of the theory of evolution in public schools in rural Pennsylvania (Raffaele, 2004).

While the debate about evolution began almost a century ago, it is not yet over. There is a long and tumultuous history behind the debate about what to include in education about evolution, but there is seemingly still no end in sight for this issue. The majority of the public has accepted the scientific facts of evolution, but there are still those with a fundamentalist Christian mindset who wish only to hear the theories of intelligent design or creationism.

II. Use of Pseudoscience and the role of Conservative Think Tanks

In both the issue of evolution and climate change, think tanks and their use of pseudoscience plays a large role in public opinion. Though think tanks often do not do any of their own research, they typically use rhetoric that is more communicable to the public than that of scientists . They can explain their “science” concepts in simple terms that are understandable to someone without an extensive science background – a feat not usually accomplished by scientists or scientific papers.

Usually, these think tanks do not attempt to convert the scientific community, but only to influence the public opinion. They attempt to reject any scientific evidence that is not obvious to the naked eye, to exploit any uncertainties in science, and to influence the public based on feelings instead of fact (Morrison, 2011). These techniques are quite effective when used correctly, as the public is not aware of the nuances of scientific writing and communication (i.e. the use of the word ‘uncertainty’).

Since these think tanks are not subject to scientific or editorial review, they can also lie. Since their only goal is to sow the seeds of doubt in the public, lying in moderation is fairly effective. Scientific literature is difficult to decipher, even for scientists, so the public would most likely never recognize a lie.

III. The Potential Future for Climate Science

Climate science in the public education forum has already started down a similar road as evolution. Without careful considerations, the debate about climate change in public education could also be stalled for years in the political arena. The debate about climate change does not have that kind of time; with every passing year without a mitigation strategy for climate change, society loses chances to keep the same quality of life it now has. To have some hope of change in the future, we need to begin educating children today in climate science.

At one point in time, evolution was deemed “in need of balance” (Morrison, 2011). Climate change has been deemed today as “in need of balance” in some states. The “balance” spoken of is the teaching of denialism, which is not real science in the case of evolution or the case of climate science. Does this balance really belong in the science classroom, or does it belong in a social studies or civics classroom? Given the beginnings of this “balancing” of climate change, the likelihood that climate change will face the same long, drawn-out time in both the political and educational arenas is high.

If the climate change debate in education follows the same trajectory as that of evolution, a large political trial on climate change being taught could result in 50 years of climate science being ignored in classrooms and textbooks without any mention of climate change. This would not only be detrimental to the state of the earth’s climate, as there would be no mitigation, but it would also cause America to fall even farther behind the rest of the world in scientific education.

The Social Disadvantages of Climate Change

Denial

I. Jobs

Across the board and throughout the United States, there is an increasing momentum being gained in green industries resulting in a steady and impressive mounting of green jobs (Wingfield, 2007). According to Forbes.com, between 2004 and 2007, green business focusing on renewable energies, waste reduction, water conservation (and a plethora of other environmental sectors), grew by a rate of 5% annually. Within the ten years leading up to 2007, the green building industry alone accrued \$12 billion of worth, up from what was once a negligible value. New research shows that the number of green jobs in the United States grew 9.1% from 1998 to 2007, which is about two-and-a-half times faster than job growth in the economy as a whole (Galbraith, 2009). Popular careers include: environmental scientists in renewable energies such as wind and solar, bio-mimicry engineers, emissions brokers, green architects, environmental journalists, and many more professions (Wingfield, 2007; The College Board). Finally, the United States Department of Labor has several reports documenting recent initiatives in green job growth. For example, according to a report on green construction, estimates show that by 2015 the non-residential green building market will be worth between \$120-145 billion (Liming, 2011). It is evident that regardless of career interests, the majority of traditional industries could be integrated with environmental studies, hence creating new and exciting job opportunities for the upcoming generation of students.

One of the major, if not the most important, environmental crises occurring presently, is the problem of climate change, specifically global warming. If students are denied access to climate change science in their classroom curriculum, they will be unable to tap into a rapidly growing market of professions and will be at a disadvantage against those students that do have climate change science implemented in their curriculum. With a growing need to mitigate and adapt to climate change, a work force will be needed that is adept in integrating traditional schools of thought and study with those that are more cutting-edge and thoughtful of potential environmental repercussions of our industry choices. Without a foundation in environmental science and studies— such as conservation psychology, sustainability science, GIS modeling, environmental

policy, environmental education, environmental law, and more— students will miss out on opportunities to not only earn a living, but make environmentally responsible business decisions.

In addition to competition among American citizens, the green job market is rapidly growing outside the United States. In the energy sector alone, analysts calculate that among new technologies in wind and solar, more than 20 million jobs may be created by 2030, contributing trillions of dollars in revenue (Bennhold, 2010). Many of these jobs will be located in China and European countries as each of their governments grapple to support their economies and revenues with green professions and business dealings.

II. Public Pressure and Climate Change Responsibility

If students are not exposed to climate change science during their K-12 education, they will remain unfamiliar with their own contribution to climate change via their household, transportation and consumer behaviors. Since they will be unintentionally contributing to climate change, other members of the public that are being taught climate change adaptation and mitigation may assign blame to them when the repercussions. Beyond resentment from peers, just recently Senate Environment and Public Works Committee Chairwoman Barbara Boxer (D-Calif.) warned those that continue to deny climate change that their participation in such an unfounded belief is endangering humankind (Restuccia, 2011). This attitude might stress relations between those that are educated about climate change and those that are not. It is imperative that all students— regardless of geographical location or type of school— receive the most up-to-date science to move forward together as a cohesive society.

The Consequences of Not Teaching Climate

Science

I. Vulnerability to Climate Change by Geographical Location

Many changes in the climate system are slow to manifest and take time and effort to notice. A temperature increase of a few degrees over many years is not noticeable to a normal person; without the help of data collection and analysis, we may not even know this change is taking place. If a change takes places quickly— for example, if the outdoor temperature increases overnight by a few degrees or it suddenly stops raining for a long period of time— we notice. Because sudden or extreme events are more evident, some of the most noticeable effects of climate change for the general public are extreme weather occurrences. Extreme weather events can many different forms – droughts, hurricanes, tornadoes, flooding, or heat waves, to name a few. The Intergovernmental Panel on Climate Change (IPCC) stated in its 2007 report for policy makers that not only is climate change undeniable, but also that it had been observed on regional scales, with changes in extreme weather events (IPCC, 2007).

Climate is not uniform over the entire planet, neither is weather. This knowledge is shared by the vast majority of the earth’s population. It is known that summer and winter do not happen at the same time in both hemispheres, and that geographic locations at lower latitudes (closer to the equator) tend to be warmer than those locations at higher latitudes. It is also known that there are places in the world called rainforests, and others called deserts. These deserts and rainforests have vastly different amounts of precipitation over a given twelve month period. Since it is clearly known that climate varies based on geographical location, why is it expected that the impacts of climate change be uniform over the entire earth?

The effects of climate change can be observed differently based on where effects are being observed. In Texas there have been increasing amount of tornadoes, severe droughts, and heat waves over the past few years. In Louisiana, there have been more hurricanes with increasing damages. In Southeast Asia, England, and China there has been increased flooding over the last decade, and in Russia there have been severe heat waves during the summer months. None of these impacts are uniform across all locations.

II. Mitigation by Region

Since the impacts of climate change can be predicted fairly easily in specific geographic locations based on extreme weather events that have already occurred and the surrounding natural systems, mitigation techniques can be developed for specific regions. These mitigation techniques can be developed for specific cities or for regions as a whole, but can be tailored for the impacts climate change will have in that specific region. Though climate is a politicized issue, preparing for an increase in extreme events should be seen as an investment, not a political choice. The choice to not prepare for extreme weather events will end up costing the government more money in the long run because of the cost of repairs after an event has taken place.

By using mitigation techniques to prepare for extreme weather events and climate change, students may also be able to avoid potentially traumatic events, like missing extended amounts of school or witnessing damages to their communities. These mitigation techniques are not political; there should be no difference in utilizing mitigation strategies for climate change and in utilizing vaccinations to mitigate the spread of disease – both are just smart practices.

III. Examples: Texas and Louisiana

Texas and Louisiana are especially vulnerable to extreme weather events. As discussed earlier, Texas has had an increase in the number of tornadoes and the severity of droughts and heat waves, and Louisiana has had an increase in both the number and severity of hurricanes. Without the instruction of climate science, students in these states will not learn about the cumulative effects of climate change and their anthropogenic causes.

Living in a region hit hard by extreme weather and climate change provides a constant reminder of the effects of climate change. Since these states are not taking advantage of this and teaching their students about the impacts humans have already had on the environment, students will not be exposed to the concept that there is a different way to view climate change.

In Texas and the surrounding states, there have been increased numbers of tornadoes in recent years. A large problem has become the fact that when tornadoes are forecast and the public is warned of them, people do not believe a tornado will actually come near their home (Mellish, 2012). Because of this disbelief and a lack of preparedness, there are many unnecessary fatalities.

If climate change were taught, people may be more likely to believe a tornado warning, knowing that extreme weather events are likely to increase.

IV. Examples: South Dakota and Utah

In the cases of South Dakota and Utah, there may not be incredibly obvious effects of climate change happening yet in either of the states, but that does not mean impacts will never hit. These states may be suffering from a case of “not in my backyard” (NIMBY) syndrome. While NIMBY usually describes the willingness of citizens to accept new developments near them as long as they are not the ones dealing with negative effects of said new development, it can also be applicable to climate change. As long as people in South Dakota and Utah are not directly feeling the impacts of climate change, they may refuse to “believe” it is happening.

By teaching their children that there is no such thing as anthropogenic climate change, they encourage a narrow view of the world. The thought process that anthropogenic climate change is not happening at all leads students in these states to believe that the choices they make do not affect anyone but themselves and their own communities. This is false; today we live in an increasingly global world, so not only will the type of light bulb a student buys impact someone in a different region, but the choices made by a student who grows up to be a business executive will also impact those in other regions of the world.

V. “Informed” Denials

Something more interesting than articles about climate change themselves may be the comments left on online forums. Many people refer to themselves as “informed deniers”. These deniers may take a surface look at the science behind climate change, but they have obviously not taken a deeper look at the science. The deniers cite “uncertainty” as a reason to believe that “[Climate change] has not happened yet”. By encouraging students to adopt this perspective, we are only ensuring another generation of people unable to separate scientific fact and their feelings about an issue.

Proposed Solutions for Climate Science Education

Climate change science needs to be taught in classrooms across America. Like teaching evolution, teachers and scientists alike have been met with controversy in some communities in attempts to teach proven and agreed upon climate science in K-12 classrooms. Since states, such as Texas and Louisiana, have passed legislation to allow climate change denial to be taught as “real science,” the education and science communities need to offer realistic solutions that allow and encourage climate change science to be taught in K-12 classrooms. People have fundamental reasons why they hold climate change denial beliefs and why they align themselves with issues such as Creationism and climate change denial. We are not proposing to attempt to change these peoples’ beliefs. Attempts to fight their beliefs and stances could potentially escalate their non-science based claims and further entrench their position.

However, like the Evolution debate, we are proposing solutions grounded in science and facts from multiple sources and a vast amount of data. The proposed solutions and our arguments are from a realistic, rationalists’ perspective. The material will be presented from a scientific perspective. Students will be exposed to the uncertainty of the science through discussion of uncertainty of modeling futures and solutions. For example, there can be discussions about uncertainty in modeling and predicting, which is inherent in all sciences. However, teachers will not be encouraged to teach uncertainty if climate change is happening because the vast majority of the science community says anthropogenic climate change is occurring. The main question is, how fast will the earth warm, and how will the Earth and humans respond?

There are several potential resolutions to the issue of teaching climate change in public school K-12 classrooms. Our solutions are meant to reach the majority of the population at large to ensure the vast majority of Americans learn climate change science. We hope the true science will reach the minds of deniers in order to be confronted with both sides of the debate. Potential solutions include the following: educate of the general public, adopt core common science standards, include climate change questions on student exams, incentivize schools with grant money to teach climate change topics, require national teacher certification exams rather than individual state licensure, include climate change content in pre-service teacher education programs, professional

development for climate change science, and create user-friendly, comprehensive, and accessible climate change curricular tools.

I. Education of the Public about the Environment and Climate Change

The general education of the public on environmental issues like climate change must begin at a young age, ideally prior to formal education occurring in kindergarten and grade school. Various studies in environmental education show that great naturalists and conservationists around the world all give similar reasons for establishing themselves in a career geared towards helping the environment. They claim primarily that early childhood experiences in wild or semi-wild natural areas were formative in their wanting to care for the environment and prevent it from degradation, thus directing them toward environmental careers. Regardless of age, national origin or gender, this seemed to hold true of the majority of participants interviewed. It is important to note that these childhood experiences were even more influential if those very natural areas in which time was spent during their youth were destroyed by anthropogenic reasons like new developments of man-made structures. Additionally, having a strong and engaged role model that encouraged contact with the environment and emphasized its inherent value also proved to be a lasting influence in directing those children to careers in environmental studies. When questioned further, the role models were mainly family members, such as parents, older siblings or even aunts and uncles (Chawla, 1999; 2007).

It appears that these two factors influenced most those people that chose environmental careers, due to the fact that they encouraged environmental sensitivity. This environmental sensitivity, or learned respect and compassion toward the environment, seems to develop at a very young age, even preceding grade school. Therefore, in order to begin educating the public about the environment in hopes that they will develop strong feelings towards protecting it from various harms such as that caused by climate change, it is imperative to increase children's exposure to the natural world between birth and five years of age. Since parents were listed as the most influential of role models, parents should be encouraged to take their children outdoors and leave them to engage in free play. Free play allows for children to engage with their natural environment through hands-on constructive play without instructions or close supervision. This creates the opportunity for children to develop skills in problem solving, observation, creativity and more, meanwhile instilling in them a sense of compassion and value for their natural world.

This is the foundation to educating the public about protecting the environment (Chawla, 2007). Parents have the opportunities to develop this environmental sensitivity by signing their children up for outdoor summer camps, letting them climb trees and play with dirt, and taking them to local forest preserves and botanical gardens, many of which are free and open to the public.

Once in school, teachers can begin to build off that foundation of environmental sensitivity by allowing students to continue bonding with the earth and developing empathy towards it.

Teachers, regardless of the presence of an active climate science curriculum in class or not, should provide opportunities to their students to study and engross themselves with their local natural environment. It is very important to realize that any environmental problem, like climate change and its negative impacts on society, needs to be avoided until middle school (Sobel, 1995). Children do not have the capacity prior to this time in their development to comprehend such negative and profound matters and in fact, exposure to these environmental challenges tends to discourage children from involving themselves from the environment more. Instead, during the formative elementary school years, an emphasis on science exposure to the water cycle and local species, for example, should take place in addition to exposure to the natural world itself. Field trips, activities in the school yard, and an introduction of plant and animal life inside the classroom can help bring students empathize with the environment.

During middle school and beyond, students can begin exploring the environment and evaluating it for themselves. Classroom discussion on pollution, biodiversity loss and climate change can tie in students' previous experiences in nature with the threat of losing such a valuable resource. Small experiments where students observe soil or water in a local ecosystem can also help them connect with their local environment and begin to understand natural and social science concepts that can be built upon when developing social action – the final step of environmental education. During junior high and high school, students can fully engage with climate change and begin formulating ways in which to prevent such harms to the environment via behavior and technological changes (Sobel, 1993).

In addition to classic environmental education, based on the empathy/exploration/social action model above, a new area of education called education for sustainability (EfS) is developing that can help incorporate climate change science into a context for students that might make the teaching of this issue more relevant and relatable (Shephard, 2008). EfS strives to not only

discuss environmental topics, but to discuss them in the context of equity and economics. This additional emphasis of environmental issues within a social justice and financial reality may allow teachers and parents to feel more comfortable having their high-school aged children discussing issues of climate change and other environmental issues, since it will have a very tangible application to their everyday lives. Environmental problems, like climate change, have multifaceted causes and consequences within the social, natural and economic sectors. For example, an increase in carbon dioxide into the atmosphere as a result of car emissions, can create flooding and drought in other parts of the world. Therein lays several compounding issues: the use of fossil fuels by one group of people causes financial losses in another in addition to threats to life both human and non-human. How does one begin to approach this complex problem? EfS allows students to be exposed to such real questions and situations so that they may better be able to handle real-world problems related to climate change as well.

II. National Core Science Standards

The United States educational system is quite unique compared to other industrialized societies, such as Australia and France. The United States Constitution gives each state the responsibility of educating its own youth. However, states have granted a great deal of control to local school districts. The result is decentralized schooling across America. There are both positive and negative ramifications to this decentralized, fragmented system. Change is easier within school districts and a person's individual voice can be heard. However, the decentralized system has allowed individuals, non-profit groups, religious organizations, and political entities to shape curriculum that is taught in schools. Students that live in Maryland will most likely receive a different education than a student who lives in California, Texas, and Michigan. Also, national legislation is difficult to pass and enforce, in this system. There are not common standards that students must achieve. Additionally, there are not common standards and certifications that public school teachers need in order to teach. Both student and teacher exams are state initiated and are different across states. It creates a disjointed nation educationally, where students can and do receive different standards and educational content across the country.

However, a major current debate is the introduction of National Standards. The goal of the Common Core State Standards are to:

“Provide a consistent, clear understanding of what students are expected to learn, so teachers and parents know what they need to do to help them. The standards are designed to be robust and relevant to the real world, reflecting the knowledge and skills that our young people need for success in college and careers. With American students fully prepared for the future, our communities will be best positioned to compete successfully in the global economy” (<http://www.corestandards.org/about-the-standards/key-points-in-english-language-arts>).

By states adopting these standards, it is meant to even the playing field across the country to ensure that all students reach a certain minimum set of standards. The Common Core State Standards includes content in English Language Arts and Mathematics. Alaska, Montana, and North Dakota have not yet adopted the core standards, but are still considering different options. However, Texas, Virginia, and Nebraska have made their own standards to have their students be college-ready.

The science education community is currently developing core standards that incorporate scientific content and practices. The science community is trying to follow the lead of the Math and Language Arts relatively successful attempt to design and implement national standards. In July 2011, a new version of the Framework for K-12 Science Education (NRC, 2011) was released. It is the precursor to the National Core Science Standards, in science, that will be released later this year.

“The overarching goal of our framework for K-12 science education is to ensure that by the end of 12th grade, all students have some appreciation of the beauty and wonder of science; possess sufficient knowledge of science and engineering to engage in public discussions on related issues; are careful consumers of scientific and technological information related to their everyday lives; are able to continue to learn about science outside school; and have the skills to enter careers of their choice, including (but not limited to) careers in science, engineering, and technology” (NRC, 2011, p. vii).

In the newest iteration of the Science Framework, climate change and human impacts on the climate are key pieces of content that should be taught in K-12 classrooms (See *Appendix B* for the standards and Framework specific to climate change science). The standards explicitly address anthropogenic climate change in the following sections: a) *Weather and Climate: What regulates weather and climate?* b) *Earth and Human Activity* c) *Human impacts on earth systems: How do Humans Change the Planet* d) *Global Climate Change: How do people model and predict the effects of human activities on Earth’s Climate*. Each section is then expanded to dictate what students should know by the end of certain grades. For example, by the end of 8th

grade, students should know the following about Global Climate Change: How do people model and predict the effects of human activities on Earth's climate?

“Human activities, such as the release of carbon dioxide from burning fossil fuels, are major factors in global warming. Reducing the level of climate change and reducing human vulnerability to whatever climate changes do occur depend on the understanding of climate science, engineering capabilities, and other kinds of knowledge, such as understanding of human behavior and on applying that knowledge wisely in decisions and activities” (NRC, 2011, p. ESS3.D)

Adopting common core science standards followed by national tests or some form of assessment to ensure comprehension and understanding across the nation would be a powerful opposition to teaching climate change denial in American public schools. States like Texas and Louisiana can currently choose not to adopt the standards, just as Texas has done with the Common Core State Standards for Math and English. However, there needs to be national legislation to strongly encourage states to adopt common standards in all core subjects. Having common national science standards will help achieve the many of the other proposed solutions that we propose to combat climate change denial being taught in schools. It will dictate national exams, have an impact on federal funding that schools receive, force pre-service and in-service educators to learn climate change science, and textbook companies and other curricular materials will be rapidly produced to help teacher adopt and enact the new standards.

III. National Tests and College-Entrance Exams

A reality of education is that the main content taught in classes is the material that will be on tests. Teachers tend to teach for the tests and students typically do not study beyond the scope of exams. There is a movement to hold teachers accountable for students' test scores. When the Common Core Science standards are adopted by all states, there will be a movement towards national exams. Climate change topics need to be tested on these exams. It should have the same number of test items as other science domains, such as biology. If a component of teacher accountability continues to be test scores, the American Federation of Teachers (AFT), a strong national teachers union, will become proponents of climate change science curricula to help its member teachers achieve necessary standards to remain employed.

Additionally, the federal government can require all students to take national exams to graduate or to receive certain funding, and the science test can include questions on climate change

science. Without teaching climate change science in classrooms, students will struggle to succeed on tests. We are not proposing high-stakes testing, but students should have enough knowledge about climate change issues to make sound, rational climate decisions. Additionally, tests are a reality of K-12 education today; if students are going to take exams, climate change science should be tested. Also, although teacher educators hope to change this phenomenon of teaching towards the test, if there are test questions on climate change, the vast majority of teachers will cover climate change topics.

Not only do climate change concepts need to be an integral part of national science exams, they need to become a part of college entrance exams, such as the SATs and ACTs. Parents will become advocates for climate change curricula in their child's school, if it will impact their child's future in areas such as college admission. For example, parents in Texas who want their child to be competitive in the college entrance process will not want their child to be placed at an automatic disadvantage because they have not learned the science that will be on the exams. Currently, the ACTs have a science section and there are SAT subject matter tests in all the major science domains. Since climate change is such an interdisciplinary subject, it can be an important component of the ACT science section and SAT subject matter tests. Additionally, a reading passage on the SAT exam is often about science content. With the knowledge that there is a chance that climate change could be a topic of one of the reading passages, this generation of helicopter parents will want their children to be exposed to the scientifically accepted version of climate change. Eventually, there would be a SAT subject matter test for climate change science because it will be a core science taught in schools.

IV. Federal Money and Grants to Teach Climate Change Curricula

Traditionally, schools have been funded from local property taxes and state funding with some federal money. However, in the mid-twentieth century, it became obvious that there were large per student expenditure discrepancies between and within states. Wealthier towns spent more money per student, while typically urban schools struggled with school infrastructure and raising funds. Also, wealthier states spent more per student in general, and the achievement gap was widening. The federal government began to intervene in attempts to level the playing field by guaranteeing some funding for schools. The current funding structure is approximately the following breakdown: 44% local government, 48% state government, and 8% federal

government. However, some districts receive more than 10% of their funds from the federal government, specifically from Title I funds (www.gao.gov/new), which are granted to districts with a certain percentage of students who qualify for free lunch programs and individuals with disabilities through the Individuals with Disabilities for Education Act. School districts now depend on federal funding to function and operate. However, some funds are more general money that goes towards schools' general operating budgets. Funds are integral to educate our children, and can therefore be used as leverage to encourage states to adopt certain core standards or curricula.

First, the federal government can become more active in curricular decisions. Since schools depend on federal funding, the federal government can withhold certain funds unless states adopt the common core state standards in all the subjects, but in this case specifically science. Second, the federal government can incentivize states through grant money. President Obama initiated competitive funding programs/grants like the Race for the Top grants. This can realistically occur for climate change education on a smaller scale. The government can incentivize schools to adopt climate change curricula and programs through grant money. The grants can include money for extra science teacher hires, science equipment, and more general funding for the school. The funds can be more general or discretionary funds, but it will encourage schools to teach climate change science.

V. National Teacher Certification Exams

Currently, there are no required common/national standards for teacher certification. If a teacher wants to teach in a Michigan Public School, she takes the courses and exams that Michigan requires to become a certified teacher. However, if she moves to New York, she would be required to take the courses and exams that New York requires to become a certified teacher. Although there is some overlap, each state determines their own standards. Without a common core set of standards for teachers, there is not a coherent and unified professional vernacular or standards that are taught throughout all schools of education across the country (Lortie, 1975). If there is a national certification exam, a section on the Earth Science, Chemistry, Physics, and Biology certification exams can be on climate change science since it is such an interdisciplinary subject. If an individual needs to understand climate change to pass the content exam to become a

teacher, more teachers will enter the classroom with exposure to and knowledge of climate change science.

Currently, there is a national teacher certification, but the process is extremely difficult and takes a great deal of time, money, and effort. Therefore, very few teachers go through the process— it is typically the best, brightest, and most committed to the profession that do so. We are not arguing that the teacher certification process should be easy; it should, in fact, limit entry.

However, a national certification process that is accessible to more teachers is necessary to ensure consistency of knowledge, practices, and high standards. It will help to ensure that students are engaging in authentic science topics and activities, such as understanding climate change and possible adaptation and mitigation options.

VI. Climate Change Content in Pre-service Teacher Education Programs

Climate change content needs to be required content in pre-service science teacher education programs. Many pre-service teachers struggle with understanding the causes and consequences of science concepts that they are going to teach (Abell, 2007, p. 1114). Climate change should be taught in pre-service teacher education programs to have a teaching force that is competent, capable, and confident in their abilities to teach climate change science.

Climate change science is incredibly interdisciplinary that many secondary and elementary school pre-service teachers would not be exposed to it in typical domain specific science class. At the University of Michigan, pre-service secondary school science teachers are required to major in a science discipline while taking education courses. However, as stated above, many students struggle with understanding the core ideas in their science courses. Additionally, many of these students are taking traditional biology, physics, and chemistry courses, which would not focus on climate change science. Secondary school science educators will typically not have an in depth understanding of the topics.

Furthermore, pre-service elementary school teachers are typically not exposed to a great deal of science content because they must be comfortable teaching all the courses.

“Twelve percent of 191 teachers surveyed in one study had no college-level science content courses and 20% had no science methods courses. Sixty-five percent had never taken part in any science in-service programs (Manning et al., 1980). A Kansas survey of

K-6 teachers found only 9% felt qualified to teach science. A similar study conducted nationwide found 22% of the K-6 teachers felt they were well-qualified to teach science as compared to 63% who thought they were well-qualified to teach reading (Gerlovich et al., 1981).” (Tilgner, 1990, p. 422).

Teachers are not feeling qualified to teach science, thus, it is not taught in K-5 classrooms. Some of the major problems for beginner teachers in addition to not feeling qualified, is not understanding science subject matter. They typically have an “unsophisticated knowledge of some specific science topics, they have unsophisticated beliefs about the nature of science, and they often avoid teaching science altogether, or focus on using science activities that are manageable and predictable because struggle with content knowledge” (Davis & Smithey, 2009, p. 747).

To help pre-service teachers with a universal issue of lack of subject matter knowledge and specifically subject matter knowledge of climate change, there should be courses taught that include and spend time on climate change science and issues at the university level. To develop the proper subject matter knowledge (SMK) which Shulman (1986) discusses as going beyond just knowing the subject knowledge; it combines content knowledge and the knowledge needed to effectively teach the content: Pedagogical Content Knowledge (PCK) (Shulman, 1986). PCK includes how to effectively teach science content and practices to students. If a teacher understands students’ prior knowledge, such as some students might come from climate change denial homes, and also common misunderstandings that the students might have about the topic, they can be more effective teachers. A teacher must have a strong understanding of the subject. To do this, they need to take college level science courses that covers climate change science.

To develop the coherence between the climate change subject matter knowledge and pedagogical content knowledge, there should be a course required for pre-service teachers that teaches the content and models the practices of conveying climate change knowledge to students. It should be presented as science and does not need to have an opinion piece. Currently, at the University of Michigan, pre-service elementary school teachers are required to take a physics course that has college level physics content. It models high leverage teacher practices (Grossman et al., 2009) and how to properly use science representations and models to convey scientific topics (Windschitl, Thompson, & Braaten, 2008).

Currently, there is a course being designed for pre-service elementary school teachers on topics in earth science and astronomy with the same overarching goals of the physics course. One of the topics discussed will be climate change and human impacts on the environment. Geologists and astronomers will teach the course. The development of the course is in its infancy, but there are hopes that the discussion session will be used to discuss how these science practices and concepts can be incorporated into the K-12 classrooms. The students will learn topics, such as the carbon cycle, energy budgets, possible mitigation plans, and the proper use of models to illustrate climate futures. These types of courses throughout teacher education programs can arm teachers with the necessary understanding of climate change to teach their students. Additionally, they will have enough knowledge to combat the claims of climate change denial and insist on teaching this topic to their classes. They will understand the uncertainty is in the models and inherent in science; there is not uncertainty in anthropogenic climate change. This will help to have well-educated climate users and consumers for the future.

VII. Professional Development Workshops

Professional development is crucial to getting climate change science into classrooms across America. Our teaching population is aging—a major concern is that there will be a dearth of teachers because many teachers are hitting retirement age. Additionally, in the science community a concern of older teachers is that they have not been exposed to some of the current science findings. Just as pre-service teachers need exposure to climate change science, current in-service teachers need the opportunity to learn or refresh their knowledge in climate change science.

Due to the aforementioned decentralized nature of education in the United States, The professional development requirements to maintain teacher certification vary across states.. However, professional development in climate change science is an integral piece to integrate this topic in schools. States, such as Indiana and Illinois are offering wonderful, hands-on climate change workshops through SEA Grants. Other states are doing similar programs, but these are still reaching limited number of teachers. Districts and states need to help scale-up the professional development opportunities in the climate change sciences. Professional development can include summer workshops, online groups and discussions, in-service days, and professional teaching communities that come together to boost subject matter knowledge in the field or discuss

issues that they are encountering teaching the subject. The National Science Teachers Association (NSTA) offers online modules for free for members to help learn climate change science and human impacts on the environment

(<http://learningcenter.nsta.org/search.aspx?action=browse&subject=38>). Professional

development in this subject is necessary to ensure that all teachers have access to the science and possibilities how to incorporate it into their classrooms.

VII. Ways to Make Teaching Climate Change Easier:

Provide Teachers with useable and easily accessible curricular materials

Currently, there is a dearth of climate change curricula that are truly accessible to students and teachers. Organizations, such as NOAA, NASA and the EPA, have education branches that have online learning materials and activities for both teachers and students. In 2010, government agencies began a concerted effort to develop online educational curricular material with the specific focus of combatting climate change denial information in the public and make the material accessible. “With opponents of U.S. climate action showing doubt about science and climate scientists, federal agencies are putting the data online and explaining it in simple language to help the public understand” (<http://insideclimatenews.org/news/20100310/nasa-noaa-step-climate-education>). NASA launched the “Warming World” series that includes videos and articles. On both the NOAA and NASA sites, officials said, “Most of the data and scientific explanations were already available, but the new sites make them easier to access with less technical writing styles and more videos and graphs” (ibid). Much of these efforts were supported by people like Senator Barbara Boxer, who is a huge proponent of making this information more accessible because she said, “These are actual measurements that can’t be argued away by people opposed to greenhouse gas regulations” (<http://insideclimatenews.org/news/20100310/nasa-noaa-step-climate-education>).

Not only have governmental agencies stepped up their attempts to get climate change science in classrooms, but organizations such as the National Science Foundation have given grants to research institutions such as the University of Michigan to develop climate change science curricula for K-12 classrooms. Currently, the Climate Change Biology Curriculum (<http://animaldiversity.ummz.umich.edu/changethinking/species>) for middle and high school students is a project designed by a team of educators and scientists at Michigan, in the Center for

Essential Science. It is designed to teach the science of climate change on an online interface with learning progressions as its foundational learning approach. The curriculum is currently being used in many middle and high schools across the country. The curriculum and the materials incorporate the climate change content and practices in the new science frameworks (NRC, 2011). The lessons and activities are on a website interface that allows the team at the University of Michigan to support students and teachers remotely and have students experience a climate change curriculum that would otherwise be difficult for individual teachers to design on their own. It covers human impacts on climate and biodiversity and major component is the use of IPCC scenarios and graphs to help students learn the science and potential solutions.

More curriculum and curricular materials like the Climate Change Biology Curriculum need to be made available to teachers to easily implement a climate change science curriculum.

Organizations such as the National Science Foundation and the Spencer Foundation are making strong efforts to fund climate change curriculum and research on how to teach it in K-12 classrooms. Efforts like these need to spread and be scaled-up to make climate change science a reality in classrooms.

Another piece is to redesign popular science textbooks to include climate change topics and units. Although Texas is one of the major purchasers of K-12 textbooks with spending about \$600 million dollars annually on average, there are several factors that are encouraging the incorporation of climate change science in K-12 science textbooks. For example, textbooks are going electronic-- electronic versions of books are cheaper to create and modify. Previously, states such as Texas and California composed the largest revenue for textbook companies, but they will become less influential in the electronic textbook creation market. As stated earlier, it will be very difficult to change the beliefs of the climate change denier camps, but others in markets that are willing and want climate change science in their curriculum can have curricular supports in textbooks with the electronic textbook market.

Beyond the textbook market, there are climate change curricular materials that can be accessed online. For example, one teacher on our research team used a textbook as a source of reference for the students and a guide to content, but the vast majority of labs and other activities were modified from Internet resources. National Geographic, the Exploratorium (<http://www.exploratorium.edu/>), NOAA, PBS, The American Museum of Natural History, and

NASA, to name a few, have free Internet resources on climate change science. They have fully developed lessons, activities, and labs for teachers to use. If reputable organizations create more climate change science resources that are accessible and in a format that can easily be modified, teachers do not have to have the knowledge or time to create their own materials, but rather modify them for their students. Teachers are busy and developing labs and other materials from scratch is extremely time consuming. Through a simple Google search, teachers should be able to access reputable climate change science curricular materials quickly and easily.

Additionally, many science teachers can become members of the National Science Teachers Association (NSTA) for a nominal fee. The NSTA's main lesson areas are based in the traditional science topics, such as Chemistry, Physics, and Biology. However, with the New Science Framework they have started to create more lessons and materials on climate change science in the Earth Science section. With this latest addition, they will need to hire more educators with a background in climate change science to continue to build on the lessons that are available to its members through published books, online resources, and professional development.

Conclusion and Action Item

Despite the consensus among the international science community as to the severity of anthropogenic climate change, many Americans continue to deny that climate change is happening, and doubt in climate science is propagated through the active campaigning and funding initiatives of a handful of conservative think tanks. Similar to the situation of evolution, climate change denial is being implemented in schools throughout the United States, whether through formal state legislature or parental pressure.

If climate change denial is adopted into school curriculum, students might be placed at a disadvantage by not receiving the most up-to-date climate science. For one, they will be unprepared to compete professionally for a growing sector of environmentally integrated jobs in the United States. As this market for green jobs and businesses grow, certain students will not have the knowledge or skill-set to grow along with this field and might therefore lose out on opportunities.

Increasing environmental sensitivity by exposing pre-school children to the environment and demonstrating environmentally responsible behaviors allows children to begin their own path to environmental stewardship at an early age. Additionally, the best way to teach elementary school children is by letting them explore and engage with their natural world. In higher grades, middle school and onward, social action can be introduced, including steps they can take to prevent climate change on an individual and societal scale.

The most realistic solutions to the issue of climate change denial in the US school systems hinge upon the adoption of the next generation of core science standards when they are released later this year (2012). There are already curricular materials being designed to meet the climate change topics and content outlined in the Framework for K-12 Science Education. Additionally, pre-service teacher programs across the country acknowledge the need to require their students to take more science courses to become more competent and confident science teachers.

For climate change science to be taught in the vast majority of classrooms across the country, it needs to overcome many major hurdles. Pre-service and in-service teachers need to have the subject matter knowledge to teach the material. There needs to be strong curricular materials

easily accessible for current teachers to use or modify for classroom use. Additionally, there needs to be incentives to teach the subject, whether through test questions, grant money, or just an individual teacher's desire to teach climate change science. Finally, individual states need to stay strong and not allow climate change denial in classrooms.

While there are many strategies to address the issue of climate change denial, in this report we have focused primarily on education, particularly k-12 public school education. We recognize the limited scope of this approach in addressing the basic mindset of climate change deniers, but our main goal is to get the vast majority of the most recent and relevant climate science to the American public in order to facilitate further discussions of climate change and strategies for adaptation and mitigation.

Action Item!



UNIVERSITY OF MICHIGAN

Action Item: Position Piece on Climate Change Science in US Schools Letter to Members of the Texas School Board of Education

Dear Mr. Clayton and Members of the Committee of Instruction,

As students, researchers, and educators examining atmospheric and climate science at the University of Michigan, we are concerned about the recent bill that encourages climate change denial in Texas K-12 classrooms. With the research that we have gathered, we feel this would place the students of Texas Public Schools at a great disadvantage.

Following the latest reports published through the Intergovernmental Panel on Climate Change (IPCC) there is a global consensus on the empirical evidence supporting contemporary climate change and its anthropogenic origins. In the new Framework for K-12 Science Education (NRC, 2011), climate science is an integral subject. Since the Frameworks will become the Core Science Standards this summer, it is imperative that Texas students receive the highest and most comprehensive level of science education that is available. Additionally, teaching climate change in schools is a wonderful opportunity to demonstrate scientific method and inquiry, and expose students to the latest science content and practices.

In addition to these educational advantages, there are other benefits to teaching climate change science to K-12 students. These multifaceted benefits include:

- An opportunity for students to develop skills and knowledge in a growing field of science and job markets.
- The education of informed consumers and global citizens that will act responsibly towards the environment.
- The understanding of the risks and ramifications of climate change on a regional and global scale. This would encourage a greater preparedness for extreme weather occurrences linked to climate change, such as tornadoes, extreme drought, and hurricanes.

As a point of reference, the recent developments in Maryland serve as an example of the successful adoption and implementation of climate science in schools (http://www.dnr.state.md.us/dnrnews/pressrelease2011/sgg_062111.asp). Maryland demonstrates the feasibility of K-12 climate science education. Texas has similar, if not greater, potential to set the standard of environmental literacy in the United States if climate science is adopted into state standards.

As you can see there are many reasons to teach climate change science without politically-motivated denial claims in Texas classrooms. We hope will you consider our position.

Yours truly,

Concerned citizens of the University of Michigan, Ann Arbor

Works Cited

- Abell, S. (2007). Research on science teacher knowledge. In S. Abell & N. Lederman (Eds.), *Handbook of research on science education* (pp. 1105-1149). Mahwah, NJ: Lawrence Erlbaum Associates.
- Banerjee, Neela. "Climate change skepticism seeps into science classrooms." *Los Angeles Times*. 16 January 2012. Borick, C and B. Rabe 2012. *Fall 2011 National Survey of American Public Opinion on Climate Change*. *Issues in Governance Studies*, n. 45. Available through: http://www.brookings.edu/~media/Files/rc/papers/2012/02_climate_change_rabe_borick/02_climate_change_rabe_borick.pdf [Accessed April 2012].
- Bennhold, K. (2010). Race Is on to Develop Green, Clean Technology. *The New York Times*. Retrieved from http://www.nytimes.com/2010/01/30/business/global/30davos.html?_r=2
- Borick, C and B. Rabe 2012. *Fall 2011 National Survey of American Public Opinion on Climate Change*. *Issues in Governance Studies*, n. 45. Available through: http://www.brookings.edu/~media/Files/rc/papers/2012/02_climate_change_rabe_borick/02_climate_change_rabe_borick.pdf [Accessed April 2012].
- Chawla, L. (1999). "Life Paths into Effective Environmental Action." *The Journal of Environmental Education*, 31(1), 15-26.
- Chawla, L. (2007). "Childhood Experiences Associated with Care for the Natural World: A Theoretical Framework for Empirical Results." *Children, Youth and Environments* 17(4), 144-170.
- Cook, J. 2012. *Global Warming & Climate Change Myths*. Skeptical Science Website. Available through: <http://www.skepticalscience.com/>. [Accessed April 2012]
- Crompton, T., Kasser, T. & World Wide Fund for Nature UK, 2009. *Meeting environmental challenges : the role of human identity*. WWF-UK, Godalming, U.K. Available through: http://assets.wwf.org.uk/downloads/meeting_environmental_challenges_the_role_of_human_identity.pdf. [Accessed April 2012]
- Davis, E. A., & Smithey, J. (2009). Beginning teachers moving toward effective elementary science teaching. *Science Education*, 93(4), 745-770.
- Galbraith, Kate. (June 10, 2009). Study Cites Strong Green Job Growth. In *The New York Times*. Retrieved March 28, 2012, from <http://green.blogs.nytimes.com/2009/06/10/study-cites-strong-green-job-growth/>.
- Gillis, J. & Kaufman, L. (2012, February 15). Leak Offers Glimpse of Campaign Against Climate Science. *The New York Times*. Available through: <http://www.nytimes.com/2012/02/16/science/earth/in-heartland-institute-leak-a-plan-to-discredit-climate-teaching.html?pagewanted=all> [Accessed April 2012].
- Gleick, P. 2011. *The Rise and Fall of Climate Change Denial*. Contribution to Forbes online. Available through: <http://www.forbes.com/sites/petergleick/2011/11/21/the-rise-and-fall-of-climate-change-denial/> [Accessed April 2012]

Grabiner, Judith V. & Miller, Peter D. "Effects of the Scopes Trials: Was it a Victory for Evolutionists?" American Association for the Advancement of Science. 6 September 1974. pp 832-837. Grossman, P., Compton, C., Igra, D., Ronfeldt, M., Shahan, E., & Williamson, P. (2009). Teaching practice: A cross-professional perspective. *Teachers College Record*, 111(9).

Grimm, Fred. "Commentary: Climate change deniers may be washed away by rising seas." The Miami Herald. 26 October 2011.

Humphrey, T. (2012, March 19). Anti-evolution class discussions get Senate's OK. Knoxnews.com. Available through: <http://www.knoxnews.com/news/2012/mar/19/anti-evolution-class-discussions-get-senates-ok/>

IPCC 2007. *IPCC Fourth Assessment Report 2007*. Geneva: IPCC Secretariat. Available through: <http://www.ipcc.ch/ipccreports/ar4-wg2.htm> [Accessed April 2012].

IPCC, 2007: Summary for Policymakers. In: *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Leiserowitz, A., Maibach, E., Roser-Renouf, C., & Hmielowski, J. D. 2011. *Politics & Global Warming: Democrats, Republicans, Independents, and the Tea Party*. Yale University and George Mason University. New Haven, CT: Yale Project on Climate Change Communication. Available through: <http://environment.yale.edu/climate/files/PoliticsGlobalWarming2011.pdf> [Accessed April 2012]

Liming, D. (2011). Careers in Green Construction. Retrieved from <http://www.bls.gov/green/construction/construction.pdf>

Lortie, D. (1975). The limits of socialization *Schoolteacher: A Sociological study*. Chicago: University of Chicago Press.

NCSE 2012. Available through: <http://ncse.com/> [Accessed April 2012].

Mellish, Kirk. "Learning from Alabama Tornadoes." Mellish's Weather Commentary. 7 February 2012.

Neela, Banerjee. "Climate Change Skepticism Seeps into Science Classrooms." Los Angeles Times. 16 January 2012.

NRC. (2011). A Framework for K-12 Science Education: Practices, Crosscutting Concepts and Core Ideas. In C. o. C. F. f. N. K.-S. E. Standards (Ed.). Washington, DC: National Academy of Sciences.

NSTA 2012. Climate Change Education Challenges Continue. NSTA Website. Available through: <http://nsta.org/publications/news/story.aspx?id=59035> [Accessed April 2011].

Morrison, David. "Science Denialism: Evolution and Climate Change." Reports of the National Center for Science Education. 2011. Oreskes, Naomi. & Conway, Erik M., 2010. *Merchants of doubt : how a handful of scientists obscured the truth on issues from tobacco smoke to global warming*. Bloomsbury Press, New York.

- Palmer, Lisa. "Public Schools' Global Warming Teachings: A Rich Field for Mining for News Stories." The Yale Forum on Climate Change and the Media. 24 June 2010. Pew Research Center for the People and the Press. <http://www.pollingreport.com/enviro.htm>
- Raffaele, Martha. "School Board OKs Challenges to Evolution." Science on MSNBC.com. 12 November 2004. Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher*, 15(2), 4-14.
- Restuccia, Andrew. (December 7, 2011). Sen. Boxer to climate-change deniers: 'You are endangering humankind'. In The Hill. Retrieved March 28, 2012, from <http://thehill.com/blogs/e2-wire/e2-wire/197815-boxer-to-climate-deniers-you-are-endangering-human-kind>.
- Shephard, K. (2008). Higher education for sustainability: seeking affective learning outcomes. *International Journal of Sustainability in Higher Education*, 9(1), 87-98. doi:10.1108/14676370810842201.
- Sobel, D. (1995). Beyond ecophobia: Reclaiming the Heart in Nature Education. *Orion Autumn*, 14(4), 11-17.
- The College Board. Career: Environmental Scientists. In bigfuture. Retrieved March 28, 2012, from <https://bigfuture.collegeboard.org/careers/environment-environmental-scientists>.
- The Wall Street Journal 2012. The Purloined Climate Papers. Available through: <http://online.wsj.com/video/opinion-the-purloined-climate-papers/F3DAA9D5-4213-4DC0-AE0D-5A3D171EB260.html> [Accessed 2012].
- Tilgner, P. J. (1990). Avoiding Science in the Elementary School. *Science Education*, 74(4), 421-431.
- Weart, S. 2011. *Global warming: How skepticism became denial*. Bulletin of the Atomic Scientists 67(1), pp. 41-50.
- Wingfield, Brian. (July 3, 2007). Special Report: Going Green-For Job Market, Green Means Growth. In Forbes.com. Retrieved March 28, 2012, from http://www.forbes.com/2007/07/02/environment-economy-jobs-biz_cx_bw_0703green_greenjobs.html.
- Windschitl, M., Thompson, J., & Braaten, M. (2008). How novice teachers appropriate epistemic discourses around model-based inquiry for use in classrooms. *Cognition and Instruction*, 26(3), 310-378.

Appendix A

Regular Session, 2008

ACT No. 473

ENROLLED

SENATE BILL NO. 733 (Substitute of Senate Bill No. 561 by Senator Nevers)

BY SENATORS NEVERS, ADLEY, AMEDEE, BROOME, CASSIDY, CHEEK, CRAVINS, CROWE, DONAHUE, DORSEY, DUPLESSIS, ERDEY, B. GAUTREAUX, N. GAUTREAUX, GRAY, HEBERT, KOSTELKA, LONG, MARTINY, MOUNT, MURRAY, RISER, SHAW, SHEPHERD, THOMPSON AND WALSWORTH AND REPRESENTATIVES ANDERS, ARMES, ARNOLD, AUBERT, AUSTIN BADON, BARROW, BURFORD, HENRY BURNS, TIM BURNS, BURRELL, CARMODY, CARTER, CHANDLER, CHANEY, CORTEZ, DANAHAY, DIXON, DOERGE, DOWNS, EDWARDS, ELLINGTON, FANNIN, FRANKLIN, GEYMAN, GISCLAIR, GREENE, ELBERT GUILLORY, MICKEY GUILLORY, GUINN, HARDY, HARRISON, HAZEL, HENDERSON, HENRY, HILL, HINES, HOFFMANN, HOWARD, HUTTER, KATZ, KLECKLEY, LABRUZZO, LAMBERT, LIGI, LITTLE, LOPINTO, McVEA, MILLS, MONICA, NORTON, PEARSON, PERRY, PUGH, RICHARD, RICHARDSON, RITCHIE, SCHRODER, SIMON, SMILEY, GARY SMITH, JANE SMITH, TUCKER, WHITE AND WILLIAMS

AN ACT

To enact R.S. 17:285.1, relative to curriculum and instruction; to provide relative to the teaching of scientific subjects in public elementary and secondary schools; to promote students' critical thinking skills and open discussion of scientific theories; to provide relative to support and guidance for teachers; to provide relative to textbooks and instructional materials; to provide for rules and regulations; to provide for effectiveness; and to provide for related matters.

Be it enacted by the Legislature of Louisiana:

Section 1. R.S. 17:285.1 is hereby enacted to read as follows:

285.1. Science education; development of critical thinking skills

A. This Section shall be known and may be cited as the "Louisiana Science Education Act."

B.(1) The State Board of Elementary and Secondary Education, upon request of a city, parish, or other local public school board, shall allow and assist teachers, principals, and other school administrators to create and foster an environment within public elementary and secondary schools that promotes critical thinking skills, logical analysis, and open and objective discussion of scientific theories being studied including, but not limited to, evolution, the origins of life, global warming, and human cloning.

Page 1 of 2

Coding: Words which are ~~struck through~~ are deletions from existing law; words **in boldface type and underscored** are additions.

(2) Such assistance shall include support and guidance for teachers regarding effective ways to help students understand, analyze, critique, and objectively review scientific theories being studied, including those enumerated in Paragraph (1) of this Subsection.

C. A teacher shall teach the material presented in the standard textbook supplied by the school system and thereafter may use supplemental textbooks and other instructional materials to help students understand, analyze, critique, and review scientific theories in an objective manner, as permitted by the city, parish, or other local public school board unless otherwise prohibited by the

State Board of Elementary and Secondary Education.

D. This Section shall not be construed to promote any religious doctrine, promote discrimination for or against a particular set of religious beliefs, or promote discrimination for or against religion or nonreligion.

E. The State Board of Elementary and Secondary Education and each city, parish, or other local public school board shall adopt and promulgate the rules and regulations necessary to implement the provisions of this Section prior to the beginning of the 2008-2009 school year.

Section 2. This Act shall become effective upon signature by the governor or, if not signed by the governor, upon expiration of the time for bills to become law without signature by the governor, as provided by Article III, Section 18 of the Constitution of Louisiana. If vetoed by the governor and subsequently approved by the legislature, this Act shall become effective on the day following such approval.

PRESIDENT OF THE SENATE

SPEAKER OF THE HOUSE OF REPRESENTATIVES

GOVERNOR OF THE STATE OF LOUISIANA

APPROVED:

Appendix B

Climate Change Standards in: A Framework for K-12 Science Education:

Practices, Crosscutting Concepts, and Core Ideas

Covered mostly in Chapter 7 of the Framework

Excerpts on climate change science from The Framework below:

ESS2.D: Weather and Climate

What regulates weather and climate?

Weather, which varies from day to day and seasonally throughout the year, is the condition of the atmosphere at a given place and time. Climate is longer term and location sensitive; it is the range of a region's weather over one year or many years, and, because it depends on latitude and geography, it varies from place to place. Weather and climate are shaped by complex interactions involving sunlight, the ocean, the atmosphere, ice, landforms, and living things. These interactions can drive changes that occur over multiple time scales—from days, weeks, and months for weather to years, decades, centuries, and beyond for climate.

The ocean exerts a major influence on weather and climate. It absorbs and stores large amounts of energy from the sun and releases it very slowly; in that way, the ocean moderates and stabilizes global climates. Energy is redistributed globally through ocean currents (e.g., the Gulf Stream) and also through atmospheric circulation (winds). Sunlight heats Earth's surface, which in turn heats the atmosphere. The resulting temperature patterns, together with Earth's rotation and the configuration of continents and oceans, control the large-scale patterns of atmospheric

circulation. Winds gain energy and water vapor content as they cross hot ocean regions, which can lead to tropical storms.

The “greenhouse effect” keeps Earth’s surface warmer than it would be otherwise. To maintain any average temperature over time, energy inputs from the sun and from radioactive decay in the earth’s interior must be balanced by energy loss due to radiation from the upper atmosphere. However, what determines the temperature at which this balance occurs is a complex set of absorption, reflection, transmission, and redistribution processes in the atmosphere and oceans that determine how long energy stays trapped in these systems before being radiated away. Certain gases in the atmosphere (water vapor, carbon dioxide, methane, and nitrous oxides), which absorb and retain energy that radiates from Earth’s surface, essentially insulate the planet. Without this phenomenon, Earth’s surface would be too cold to be habitable. However, changes in the atmosphere, such as increases in carbon dioxide, can make regions of Earth too hot to be habitable by many species.

Climate changes, which are defined as significant and persistent changes in an area’s average or extreme weather conditions, can occur if any of Earth’s systems change (e.g., composition of the atmosphere, reflectivity of Earth’s surface). Positive feedback loops can amplify the impacts of these effects and trigger relatively abrupt changes in the climate system; negative feedback loops tend to maintain stable climate conditions.

Some climate changes in Earth’s history were rapid shifts (caused by events, such as volcanic eruptions and meteoric impacts, that suddenly put a large amount of particulate matter into the atmosphere or by abrupt changes in ocean currents); other climate changes were gradual and

longer term—due, for example, to solar output variations, shifts in the tilt of Earth’s axis, or atmospheric change due to the rise of plants and other life forms that modified the atmosphere via photosynthesis. Scientists can infer these changes from geological evidence.

Natural factors that cause climate changes over human time scales (tens or hundreds of years) include variations in the sun’s energy output, ocean circulation patterns, atmospheric composition, and volcanic activity. (See ESS3.D for a detailed discussion of human activities and global climate change). When ocean currents change their flow patterns, such as during El Niño Southern Oscillation conditions, some global regions become warmer or wetter and others become colder or drier. Cumulative increases in the atmospheric concentration of carbon dioxide and other greenhouse gases, whether arising from natural sources or human industrial activity (see ESS3.D), increase the capacity of Earth to retain energy. Changes in surface or atmospheric reflectivity change the amount of energy from the sun that enters the planetary system. Icy surfaces, clouds, aerosols, and larger particles in the atmosphere, such as from volcanic ash, reflect sunlight and thereby decreasing the amount of solar energy that can enter the weather/climate system. Conversely, dark surfaces (i.e. roads, most buildings) absorb sunlight and thus increase the energy entering the system.

Grade Band Endpoints for ESS2.D

By the end of grade 2. Weather is the combination of sunlight, wind, snow or rain, and temperature in a particular region at a particular time. People measure these conditions to describe and record the weather and to notice patterns over time.

By the end of grade 5. Weather is the minute-by-minute to day-by-day variation of the atmosphere's condition on a local scale. Scientists record the patterns of the weather across different times and areas so that they can make predictions about what kind of weather might happen next. Climate describes the ranges of an area's typical weather conditions and the extent to which those conditions vary over years to centuries.

By the end of grade 8. Weather and climate are influenced by interactions involving sunlight, the ocean, the atmosphere, ice, landforms, and living things. These interactions vary with latitude, altitude, and local and regional geography, all of which can affect oceanic and atmospheric flow patterns. Because these patterns are so complex, weather can be predicted only probabilistically. The ocean exerts a major influence on weather and climate by absorbing energy from the sun, releasing it over time, and globally redistributing it through ocean currents. Greenhouse gases in the atmosphere absorb and retain the energy radiated from land and ocean surfaces, thereby regulating Earth's average surface temperature and keeping it habitable.

By the end of grade 12. Global climate is a dynamic balance on many different time scales among energy from the sun falling on Earth; the energy's reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems; and the energy's reradiation into space. Climate change can occur if any part of Earth's systems is altered. Geological evidence indicates that past climate changes were either sudden changes caused by alterations in the atmosphere; longer term changes (e.g., ice ages) due to variations in solar output, Earth's orbit, or the tilt of its axis; or even more gradual atmospheric changes due to plants and other organisms that captured carbon dioxide and released oxygen. The time scales of these changes varied from a few to millions of years. Changes in the atmosphere due to human activity have

increased carbon dioxide concentrations and thus affect climate (link to ESS3.D).

Global climate models incorporate scientists' best knowledge of physical and chemical processes and of the interactions of relevant systems. They are tested by their ability to fit past climate variations. Current models predict that, although future regional climate changes will be complex and varied, average global temperatures will continue to rise. The outcomes predicted by global climate models strongly depend on the amounts of human-generated greenhouse gases added to the atmosphere each year and by the ways in which these gases are absorbed by the ocean and the biosphere. Hence the outcomes depend on human behaviors (link to ESS3.D) as well as on natural factors that involve complex feedbacks among Earth's systems (link to ESS2.A).

**CORE IDEA ESS3:
EARTH AND HUMAN ACTIVITY**

How do Earth's surface processes and human activities affect each other?

The earth's surface processes affect and are affected by human activities. Humans depend on all of the planet's systems for a variety of resources, some of which are renewable or replaceable and some of which are not. Natural hazards and other geological events can significantly alter human populations and activities. Human activities, in turn, can contribute to the frequency and intensity of some natural hazards. Indeed, humans have become one of the most significant agents of change in the earth's surface systems. In particular, it has been shown that climate change—which could have large consequences for all of Earth's surface systems, including the biosphere—is driven not only by natural effects but also by human activities. Sustaining the biosphere will require detailed knowledge and modeling of the factors that affect climate, coupled with the responsible management of natural resources.

ESS3.C: Human Impacts on Earth Systems

How do humans change the planet?

7-17

Recorded history, as well as chemical and geological evidence, indicates that human activities in agriculture, industry, and everyday life have had major impacts on the land, rivers, ocean, air, and even outer space. Humans affect the quality, availability, and distribution of Earth's water through the modification of streams, lakes, and groundwater. Large areas of land, including such delicate ecosystems as wetlands, forests, and grasslands, are being transformed by human agriculture, mining, and the expansion of settlements and roads. Human activities now cause land erosion and soil movement annually that exceed all natural processes. Air and water pollution caused by human activities affect the condition of the atmosphere and of rivers and lakes, with damaging effects on other species and on human health. The activities of humans have significantly altered the biosphere, changing or destroying natural habitats and causing the extinction of many living species. These changes also affect the viability of agriculture or fisheries to support human populations. Land use patterns for agriculture and ocean use patterns for fishing are affected not only by changes in population and needs but also by changes in climate or local conditions (such as desertification due to overuse, depletion of fish populations by overextraction).

Thus humans have become one of the most significant agents of change in the near surface earth system. And because all of Earth's subsystems are interconnected, changes in one system can produce unforeseen changes in others

The activities and advanced technologies that have built and maintained human civilizations clearly have large consequences for the sustainability of these civilizations and the ecosystems

with which they interact. As the human population grows and per-capita consumption of natural resources increases to provide a greater percentage of people with more developed lifestyles and greater longevity, so do the human impacts on the planet.

Some negative effects of human activities are reversible with informed and responsible management. For example, communities are doing many things to help protect Earth's resources and environments. They are treating sewage, reducing the amount of materials they use, and reusing and recycling materials. Regulations regarding water and air pollution have greatly reduced acid rain and stream pollution, and international treaties on the use of certain refrigerant gases have halted the growth of the annual ozone hole over Antarctica. Regulation of fishing and the development of marine preserves can help restore and maintain fish populations. In addition, the development of alternative energy sources can reduce the environmental impacts otherwise caused by the use of fossil fuels.

The sustainability of human societies and of the biodiversity that supports them require responsible management of natural resources not only to reduce existing adverse impacts but also to prevent such impacts to the extent possible. Scientists and engineers can make major contributions by developing technologies that produce less pollution and waste and that preclude ecosystem degradation.

ESS3.D: Global Climate Change

How do people model and predict the effects of human activities on Earth's climate?

7-18

Global climate change, shown to be driven by both natural phenomena and by human activities, could have large consequences for all of Earth's surface systems, including the biosphere (see

ESS3.C for a general discussion of climate). Humans are now so numerous and resource-dependent that their activities affect every part of the environment, from outer space and the stratosphere to the deepest ocean. However, by using science-based predictive models, humans can anticipate long-term change more effectively than ever before and plan accordingly.

Global changes usually happen too slowly for individuals to recognize, but accumulated human knowledge, together with further scientific research, can help people learn more about these challenges and guide their responses. For example, there are historical records of weather conditions and of the times when plants bloom, animals give birth or migrate, and lakes and rivers freeze and thaw. And scientists can deduce long-past climate conditions from such sources as fossils, pollen grains found in sediments, and isotope ratios in samples of ancient materials.

Scientists build mathematical climate models that simulate the underlying physics and chemistry of the many Earth systems and their complex interactions with each other. These computational models summarize the existing evidence, are tested for their ability to match past patterns, and are then used (together with other kinds of computer models) to forecast how the future may be affected by human activities. The impacts of climate change are uneven and may affect some regions, species, or human populations more severely than others.

Climate models are important tools for predicting, for example, when and where new water supplies will be needed, when and which natural resources will become scarce, how weather patterns may change and with what consequences, whether proposed technological concepts for controlling greenhouse gases will work, and how soon people will have to leave low-lying coastal areas if sea levels continue to rise. Meanwhile, important discoveries are being made—

for example, about how the biosphere is responding to the climate changes that have already occurred, how the atmosphere is responding to changes in anthropogenic greenhouse gas emissions, and how greenhouse gases move between the ocean and the atmosphere over long periods. Such information, from models and other scientific and engineering efforts, will continue to be essential to planning for humanity's—and the global climate's—future.

It is important to note that although forecasting the consequences of environmental change is crucial to society, it involves so many complex phenomena and uncertainties that predictions, particularly long-term predictions, always have uncertainties. These arise not only from uncertainties in the underlying science but also from uncertainties about behavioral, economic, and political factors that affect human activity and changes in activity in response to recognition of the problem. However, it is clear not only that human activities play a major role in climate change but also that impacts of climate change, for example increased frequency of severe storms due to ocean warming, have begun to influence human activities. The prospect of future impacts of climate change due to further increases in atmospheric carbon is prompting consideration of how to avoid or restrict such increases.

Grade Band Endpoints for ESS 3.D

By the end of grade 2. Intentionally left blank.

By the end of grade 5. If Earth's global mean temperature continues to rise, the lives of humans and other organisms will be affected in many different ways.

By the end of grade 8. Human activities, such as the release of carbon dioxide from burning fossil fuels, are major factors in global warming. Reducing the level of climate change and reducing human vulnerability to whatever climate changes do occur depend on the understanding of climate science, engineering capabilities, and other kinds of knowledge, such as understanding of human behavior and on applying that knowledge wisely in decisions and activities.

By the end of grade 12. Because global climate changes usually happen too slowly for individuals to recognize them directly, scientific and engineering research—much of it based on studying and modeling past climate patterns—is essential. The current situation is novel, not only because the magnitudes of humans’ impacts are significant on a global scale but also because humans’ abilities to model, predict, and manage future impacts are greater than ever before. Through computer simulations and other studies, important discoveries are still being made about how the ocean, the atmosphere, and the biosphere interact and are modified in response to human activities, as well as to changes in human activities. Thus science and engineering will be essential both to understanding the possible impacts of global climate change and to informing decisions about how to slow its rate and consequences—for humanity as well as for the rest of the planet.