Activities for Conceptualizing Climate and Climate Change

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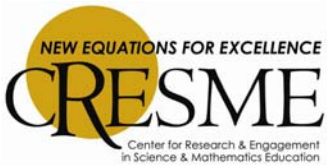

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Introduction to the Climate and Climate Change Activities

Foreword

These climate and climate change activities are designed to supplement and support the existing curriculum, and are consistent with the *National Science Education Standards*. The activities were developed and tested by a team composed of teachers, scientists, and professionals with expertise in pedagogy and climate and climate change science. The activities incorporate real scientific data and require students to interpret, analyze, and represent data and scientific concepts. The activities facilitate student learning by emphasizing the application of scientific concepts to real-life scenarios. They were designed in line with a conceptual framework and based on the research on student conceptions about climate and climate change. In terms of pedagogy, the activities promote active learning and collaboration and include suggested assessment tools. The set of activities comprises supporting materials that visually represent scientific concepts, student printed materials, teacher guides, background information, and suggested resources. These activities can be distributed to teachers and copied for classroom use by teachers at no cost, but they may not be sold. For more information and additional resources visit our web site at: http://iclimate.org/ccc

Teaching and Learning about Climate and Climate Change

The Intergovernmental Panel on Climate Change (IPCC) has concluded that global warming is inevitable and that human activity is likely to be the main cause. The National Research Council's *Grand Challenges in Environmental Sciences* (NRC, 2000a) identified eight "grand challenges," four of which are directly linked to climate and climate change. Additionally, the National Science Foundation has identified climate prediction and variability as a core study area. It is vital that students learn about climate and climate change. Study areas especially highlighted and relevant to the educational needs include: understanding climate variability, the interactions of natural and human systems, and the role of climate data and modeling in socioeconomic decision-making (NRC, 2000b).

Teaching about climate change and environmental issues is essential for developing well rounded students, and for overcoming a critical deficiency in atmospheric science and climatology curricula (Serafin et al. 1991). The investigation of climate change and climate variability provides a natural context for studying science through personal and social applications. An understanding that is essential if future citizens are to assume responsibility for the management and policymaking decisions facing our planet (Brown, 1992; Bybee, 1993).

Teaching about climate change, however, is conceptually challenging. Although students can collect local weather data and relate this data to local climate, they cannot monitor climate change due to time and scale issues. Thus, in order to learn about climate change it is necessary for students to interpret, analyze, explain and evaluate historical data and model-based data projections. Students, however, have difficulty distinguishing (a) between an explanation and the evidence supporting it and (b) between the description of evidence and the interpretation of evidence (Roseberry, Warren, & Conant, 1992). Students also tend to focus on differences in patterns or relationships versus similarities. Interpreting graphs may also be difficult. Students tend not to realize that the slope of a graph is a measure of rate (McDermott, Rosenquist, & van Zee, 1987) and they have difficulty with the notion of interval scale (Leinhardt, Zaslavsky, & Stein, 1990) or the effect of a change in scale on the graph's appearance (Kerslake, 1981). Students tend to interpret graphs point-by-point, ignoring the global features or patterns. Data handling can be problematic for students. Students may have difficulty in calculating a mean and in comparing the means of different data sets (Mokros & Russell, 1992). Most students accept arguments or explanations based on inadequate sample size (Jungwirth & Dreyfus, 1992) and tend to draw causal relations among variables. Given these challenges, it is important that students be given the opportunity to develop the knowledge and skills to analyze and think about climate change data, to communicate and debate ideas and perspectives about climate change, and to make informed decisions concerning their own personal actions and behaviors. The enclosed activities provide the teacher with the materials and resources to support students in meeting the challenge of understanding climate change.

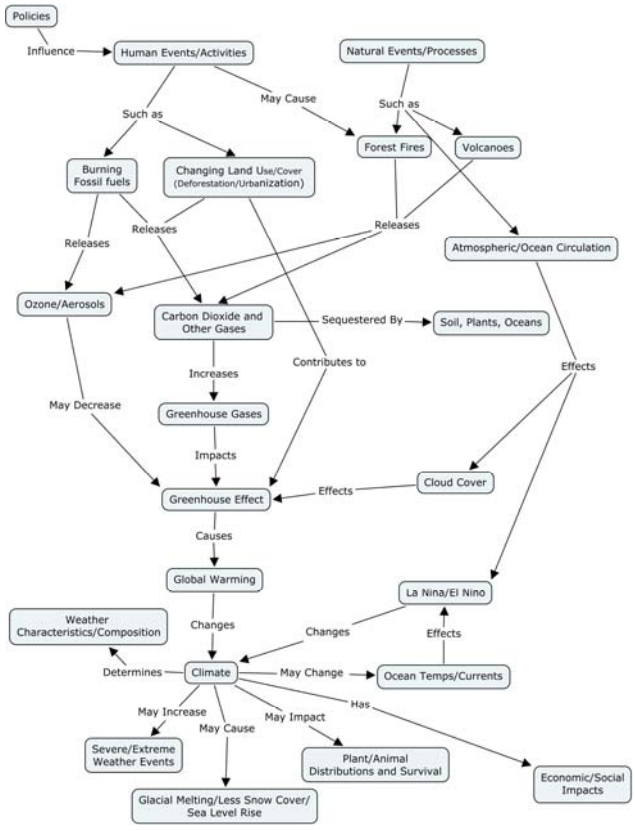

Figure 1: Conceptual Framework

Conceptual Framework and Climate Change

The conceptual framework shown in Figure 1 serves as a curriculum guide for the activities in this guidebook. The framework illustrates the connection between scientific concepts and provides a general overview of climate change. The framework informed the development of the activities within this guidebook. Each activity links to one or more of the concepts represented in the conceptual framework. The conceptual

framework was developed based on climate and climate change science.

The Intergovernmental Panel on Climate Change (IPCC) has stated that global atmospheric concentrations of greenhouse gases--carbon dioxide, methane, and nitrous oxide--have increased since 1750 as a result of human activities. The increase in carbon dioxide is primarily due to the burning of fossil fuels and land-use change, while the increase in methane and nitrous oxide are primarily due to agriculture (IPCC, 2007). This increase in greenhouse gases has been linked to global warming, evident from increases in average global air and ocean temperatures, melting snow and ice, and sea level rise (IPCC, 2007). Continued greenhouse gas emissions at current or increased rates would likely cause further global warming and climate change with a projected 0.1^{o} C to 0.2^{o} C increase per decade in global temperature (IPCC, 2007). The IPCC (2007) projects that further global warming is likely to result in more:

- warming over land and at northern latitudes
- snow cover contraction and permafrost thaw
- sea ice melt and loss
- frequent heat waves and heavy precipitation events
- intense tropical cyclones

About the Activities

The activities are designed to promote active learning, viewing students as active thinkers who construct their own understandings. Constructivism emphasizes that 1) knowledge is actively constructed by the individual and that it is not passively received from others; 2) prior understandings influence knowledge construction; 3) knowledge is constructed by physically and mentally acting on phenomena and ideas and by integrating new experiences into existing knowledge structures (assimilation) or by creating new knowledge structures (accommodation); and 4) knowledge construction is influenced by social interaction with other learners' and the teacher. The activities, therefore, require that students:

- interpret, visualize, and transform scientific data and apply scientific concepts
- analyze, evaluate, and explain scientific evidence and information
- discus and represent ideas and different perspectives
- work collaboratively to make decisions and draw conclusions

Three distinct, data-rich activity types are included: data interpretation/visualization, case study, and structured controversy. The data interpretation/visualization activities use state, local, and national climate data sets and diagrams, which students interpret, analyze and transform as a means to conceptualizing climate and climate change. The data interpretation/visualization activities are scenario-based and designed to engage students through the use of guiding questions. The case studies incorporate rich data sets and textual information as evidence that students analyze, evaluate, explain and apply. The case studies contain images, data tables, graphs, diagrams, and maps. The case studies are designed following the standard case study format:

- case narrative that includes a description of the issue, context, and scientific information and data used by students to answer guiding questions.
- a series of questions embedded within the narrative that promotes students to analyze the data and examine the issues as they progress through the case study.

The structured controversies follow the Johnson and Johnson (1985) model. Students are provided with a brief background to set the context of the controversy and are asked to state and explain their position on an issue related to climate change. Working collaboratively, students are assigned a position and review scientific documents and essays in order to write a brief in support of the position. Students then discuss the strengths and weaknesses of the brief with other students and construct a consensus brief. All activities begin by eliciting students' prior conceptions and end by encouraging students to reflect on changes in their prior conceptions. This provides teachers with an opportunity to assess students' thinking and learning. A variety of assessment opportunities are embedded in the activities and included in the teacher guide.

Implementing the Activities

Climate and Climate Change Module	Activity Title/Topic				
Fossil Fuels and Greenhouse Gases	Energy, Fossil Fuels, and the Carbon Cycle	Fossil Fuel Use and Carbon Dioxide Emissions	Case Study: Carbon Dioxide and Global Warming: What is the evidence?	Your Family's Carbon Footprint	Climate Change: The Debate
Climate and Severe/Extreme Weather	Weather and Climate	Climate Change or Climate Variability	Mid-Latitude Cyclones and Climate Change	Case Study: Hurricanes and Global Climate Change	
Climate Change and Ecological Impact	Climate Change and the Arctic Ecosystem	Climate Change and Biomes	Case Study: Climate Change and the Arctic Ecosystem	Bird Migration and Climate Change	
Natural Processes and Climate Change	El Niño and Global Warming	Volcanoes and Global Warming	Milankovitch Cycles Case Study	Sun Spot Activity Case Study	

Table1: The Climate and Climate Change Activities and Topics.

The activities are designed to cover a number of different climate and climate change topics that may be taught as stand alone lessons; they are designed to supplement the existing science curriculum. Examples of the different activities and climate and climate change topics are listed in Table 1. Links to the student activities, teacher guides, and PowerPoint slides are located at http://iclimate.org/ccc. The activities may be combined in a number of different ways to cover a

similar climate or climate change topic, enabling teachers to update their curricula and to respond to students' interest in current scientific issues. The emphasis on inquiry and collaborative learning support students' knowledge construction and promotes a community of science learners. The target audience is ninth-grade, with a grade range between 7th and 11th grade.

Correlation to the *National Science Education Standards*

Activities for Conceptualizing Climate and Climate Change aligns with the National Research Council's *National Science Education Standards* (NRC, 1996). The activities incorporate teaching strategies and science content that meet the *National Science Education Standards*. For this reason, they can assist teachers in planning and implementing a standards-based program. The activities may be linked to a number of science content standards. An example of the correlation to the *National Science Education Standards*, grades 9-12, is illustrated in Table 2. The activities are also aligned with the NRC (2000) essential features of classroom inquiry:

- Learners engaged by scientifically oriented **QUESTIONS**.
- Learners give priority to **EVIDENCE**.
- Learners formulate **EXPLANATIONS** from evidence.
- Learners **EVALUATE** explanations.
- Learners **COMMUNICATE** and **JUSTIFY** explanations.

National Science Education Standard Excerpt	Activities
Chemical Reactions Some reactions, such as the burning of fossil fuels, release large amounts of energy …	Energy, Fossil Fuels, and the Carbon Cycle
Interdependence of Organisms Human destruction of habitats through direct harvesting, pollution, atmospheric changes, and other factors is threatening current global stability …	Climate Change and Natural Habitats (Biomes)
Energy in the Earth System Global climate is determined by energy transfer from the sun at and near the earth's surface. This energy transfer is influenced by dynamic processes …	Weather and Climate
Geochemical Cycles The earth is a system containing a fixed amount of each stable chemical atom or element. … Each element on earth moves among reservoirs in the solid earth, oceans, atmosphere, and organisms as part of geochemical cycles.	Case Study: Carbon Dioxide and Global Warming: What is the evidence?
Environmental Quality Natural ecosystems provide an array of basic processes that affect humans. Those processes include maintenance of the quality of the atmosphere, generation of soils, control of the hydrologic cycle, disposal of wastes, and recycling of nutrients. Humans are changing many of these basic processes, and the changes may be detrimental to humans.	Case Study: Climate Change and the Arctic Ecosystem

Table2: Example of the Correlation to the National Science Education Standards.

Student Conceptions about Climate and Climate Change

Although a number of studies have investigated students' ideas about the Earth's shape and gravity (e.g., Nussbaum, 1985; Baxter, 1989; & Vosniadou & Brewer, 1990), lunar phases (e.g., Baxter, 1989; Stahly, Krockover, & Shepardson, 1999), rocks and rock cycle (e.g., Happs, 1985), and seasons (e.g., Baxter, 1989), there is little breadth in the research on student conceptions about geoscience concepts (Manduca, Mogk, Stillings, 2002). Furthermore, little research has been conducted that investigates students' conceptions about climate and climate change. A summary review of this research is presented in Table 3. For a more detailed review visit our web site at: http://iclimate.org/ccc

Student Conceptions about Climate and Climate Change	Author(s)
Confusion between climate and weather	Pruneau, Gravel, Courque, & Langis (2003) Growda, Fox, & Magelky (1997)
Climate change is caused by the sun's rays getting trapped in the ozone; the sun's rays currently hit more places on the Earth	Pruneau, Gravel, Courque, & Langis (2003)
Climate change is caused by general air pollution	Boyes & Stanisstrret (1997) Growda, Fox, & Magelky (1997) Boyes, Chambers, & Stanisstreet (1995) Boyes & Stanisstreet (1993)
Climate change is caused by the ozone hole	Rebich & Gautier (2005) Pruneau, Gravel, Courque, & Langis (2003) Österlind (2005) Pruneau, Moncton, Liboiron, & Vrain (2001) Boyes, Stanisstreet, & Papantoniou (1999) Koulaidis & Christidou (1999) Mason & Santi (1998) Growda, Fox, & Magelky (1997) Dove (1996) Boyes, Chambers, & Stanisstreet (1995)
Confusion between the greenhouse effect and global warming	Rebich & Gautier (2005)

Table 3: Summary Review of the Research on Students Conceptions

Our own research has shown that students' conceptions about climate change include the following ideas:

- Carbon dioxide is viewed as the only greenhouse gas; students do not realize that methane, nitrous oxide, and water vapor are also greenhouse gases.
- Carbon dioxide is seen only as an air pollutant and not as naturally occurring; similarly, water vapor and methane are not viewed as naturally occurring in the atmosphere.
- Carbon dioxide forms a layer in the atmosphere that traps heat.
- All radiated heat is trapped by the atmosphere; that is, no heat is radiated into space.

For more information about our research findings visit our web site at: http://iclimate.org/ccc

This research on students' conceptions served as the building block for the activities included in this resource packet. By designing instructional materials and activities that build from students' conceptions and link to the scientific perspective, learning experiences sequence instruction in a way that moves students toward scientific conceptualization—curricular continuity (Driver, Squires, Rushworth, & Wood-Robinson, 1994).

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