TEACHING CLIMATE SCIENCE LITERACY

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Abstract Climate Science Literacy is an understanding of individual's influence on climate and climate's influence on individual level and society. A climate-literate person understands the essential principles of Earth's climate system, knows how to assess scientifically credible information about climate, communicates about climate and climate change in a meaningful way, and is able to make informed and responsible decisions with regard to actions that may affect climate. This paper suggests that education responses are needed which attend to provision of both appropriate educational infrastructure and relevant knowledge and skills.

1. Introduction

Climate Change is one of the most pressing global issues of our time. Human activities increasingly influence the Earth's climate (IPCC, 2007) and ecosystems (MEA, 2005). The impacts of climate change are already being observed and are projected to become more pronounced. Over the past 150 years, mean temperature has increased by 0.8 ºC globally and by about 1 ºC in Europe. Ten last years (2000–2009) were the 10 warmest years in the instrumental record of global surface temperature (since 1850). Without global action to limit emissions, the IPCC (2007) expects that global temperatures may increase further by 1.8 to 4.0 ºC by 2100. This means that temperature increase since pre-industrial times would exceed 2 °C. Beyond this threshold irreversible and possibly catastrophic changes become far more likely. To halt climate change, global greenhouse gas emissions must be reduced significantly, and policies are put in place to do so. The main sources of man-made greenhouse gases are: burning of fossil fuels in electricity generation, transport, industry and households; agriculture and land use changes like deforestation; land filling of waste; and use of industrial fluorinated gases. Bit unfortunately, even if policies and efforts to reduce emissions are effective, some climate change is inevitable. We must therefore also develop strategies to adapt to the impacts of climate change in Europe and especially beyond, since the least developed countries are among the most vulnerable, having the least financial and technical capacity to adapt. It becomes obvious that besides communication and awareness raising programs, specific educational approaches and training programs are needed to develop and promote knowledge and competencies in the field of climate change (AAAS, 2007).

2. Teaching climate change

For addressing the complex multi-stakeholder and multilevel challenges associated with climate change mitigation and adaptation an appropriate knowledge base is needed not only among public authorities and academia but also among civil society, business sector etc. in order to have problem aware constituencies in the countries of the world supporting with their attitudes and actions governments towards bold future oriented global climate change action (Burandt and Barth, 2010).

Climate and changes in climate have influenced in the past and will continue to influence what kinds of life forms are able to exist. Yet climate change is a phenomenon with which we humans have little experience, at least in historic times, and teaching about it presents special challenges to educators. Working with a complex topic like climate change is challenging both for students and teachers. Understanding the basic principles that contribute to maintaining and causing changes in weather and climate increases our ability to forecast and moderate the effects of

weather and to make informed decisions about human activities that may contribute to climate change.

Climate science, like any other scientific discipline, develops through vigorous debates between experts, but there is an overwhelming consensus regarding its fundamentals. Climate science has a firm basis in physics and is supported by a wealth of evidence from real world observations. But climate change is not just an environmental problem. It is an economic problem, a political problem, an international security problem (Table 1). In a warmer world, accessibility to food, water, raw materials, and energy are likely to change. Human health, biodiversity, economic stability, and national security are also expected to be affected by climate change. Climate model projections suggest that negative effects of climate change will significantly outweigh positive ones.

Table 1. Possible impacts of climate change due to changes in extreme weather and climate events, based on projections to the mid to late 21st century (Modified after IPCC, 2007).

Phenomena and direction of trend	**Likelihood of future trend**	**Major projected impacts by sector**			
		Agriculture, forestry	**Water resources**	**Human health**	**Industry/settlement/ Society**
Fewer cold days/nights; more frequent hot days/ nights over most land areas.	Virtually certain	Increased yields in colder environments; decreased yields in warmer environments	Effects on water resources relying on snow melt; increased evapotranspiration rates	Reduced human mortality from decreased cold exposure	Reduced energy demand for heating; increased demand for cooling; declining air quality in cities; effects on winter tourism
Warm spells/heat waves: frequency increases over most land areas	Very likely	Reduced yields in warmer regions due to heat stress; fire danger increase	Increased water demand; water quality problems, e.g., algal blooms	Increased risk of heat-related mortality, especially for the elderly, chronically sick, very young and socially-isolated	Reduction in quality of life for people in warm areas without air conditioning; impacts on elderly, very young and poor; reduced thermoelectric power production efficiency; disruption to commerce
Heavy precipitation events: frequency increases over most areas	Very likely	Damage to crops; soil erosion, inability to cultivate land due to water logging of soils	Adverse effects on quality of surface and groundwater; contamination of water supply; water scarcity may be relieved	Increased risk of deaths, injuries, infectious, respiratory and skin diseases, post traumatic stress disorders	Disruption of settlements, commerce, transport and societies due to flooding; pressures on urban and rural infrastructures
Area affected by drought: increases	Likely	Land degradation, lower yields/crop damage and failure; increased livestock deaths; increased risk of wildfire	More widespread water stress	Increased risk of food and water shortage; increased risk of malnutrition; increased risk of water- and food-borne diseases	Water shortages for settlements, industry and societies; reduced hydropower generation potentials; potentials for population migration
Sea level rise	Likely	Salinisation of irrigation and well water	Decreased freshwater availability due to saltwater intrusion	Increased risk of deaths and injuries by drowning in floods; migration-related health effects	Costs of coastal protection, land-use relocation; Displacement of human populations, abandonment of settlements, relocation of infrastructure

Despite growing scientific evidence that global warming will have serious impacts worldwide (Richardson, 2009), lately public opinion is moving in the opposite direction. Over the past year many countries have experienced rising unemployment, public frustration with financial crisis, largely pushing climate change out of the news. Meanwhile, a set of emails stolen from climate

scientists and used by critics to allege scientific misconduct may have contributed to an erosion of public trust in climate science. It is also clear that public understanding of climate change fundamentals - that it is happening, is human caused, and will have serious consequences for human societies and natural ecosystems around the world - is heading in the wrong direction. Students of all ages (including college students and adults) still have difficulty understanding what causes climate change. These findings underscore the critical need for more and improved climate change education and communication (Bangay and Blum, 2010).

Climate change science is complex and can certainly be confusing (Figure 1). It is highly interdisciplinary, cutting across numerous disciplines. Many if not most science educators teaching traditional biology, chemistry and physics may never have been trained in the basics of climate science. Earth sciences have also been traditionally rooted in geology, where rocks rule and deep time prevails. Climate fits between geological and meteorological processes, and all too often falls through the disciplinary cracks. There are many well-written and authoritative books for a general audience that can help educators and others understand the science of climate change and its environmental and societal impacts. Also there is an abundance of information and materials available online for science educators and communicators, like official site of the Intergovernmental Panel on Climate Change from which all of the IPCC reports are available for download. Some excellent Web sites, which provide access to a variety of authoritative resources from government, academic, and scientific organizations are given in Table 2.

Table 2: Some excellent Web sites, which provide access to a variety of authoritative resources from government, academic, and scientific organizations

Institution (alphabetical order)	**Web site**
AAAS Global Climate-Change Resources	http://www.aaas.org/climate
European Environment Agency	http://www.eea.europa.eu/themes/climate
Hadley Centre for Climate Change : the UK's official centre for climate change research.	http://www.metoffice.gov.uk/climatechange/science/hadley centre/
Intergovernmental Panel on Climate Change (IPCC)	http://www.ipcc.ch/
James Hansen : articles and presentations on timely and important issues in climate science.	www.columbia.edu/~jeh1
National Oceanic & Atmospheric Administration (NOAA), National Climate Data Center	http://www.ncdc.noaa.gov/oa/climate/globalwarming.html www.education.noaa.gov
National Center for Atmospheric Research (Colorado USA)	http://www.ucar.edu/research/climate/ http://www.eo.ucar.edu/basics/index.html
Potsdam Institute for Climate Impact Research (PIK)	http://www.pik-potsdam.de/
RealClimate: Climate scientists respond to issues that arise in the popular discourse	www.realclimate.org
University of Copenhagen	www.copenhagendiagnosis.com
World Climate Research Programme (WCRP)	http://wcrp.wmo.int/wcrp-index.html

Most students learn the basics of weather at a young age. It's a good place to start—observing local weather events and seasonal changes. But climate, while obviously related to weather is inherently different, requiring different theories, models and pedagogy. In many countries, few teachers have training—or the time or mandate—to dig deeply into climate processes. When climate change is taught, it is often ad hoc, emphasizing polar bears and carbon calculators over in-depth understanding of carbon, climate and complex interactions. This is a pity, because interest in climate change issues provides a great opportunity to talk about basic science, as well. Furthermore climate change science is one of the first science topics where a social science physical science collaboration is required.

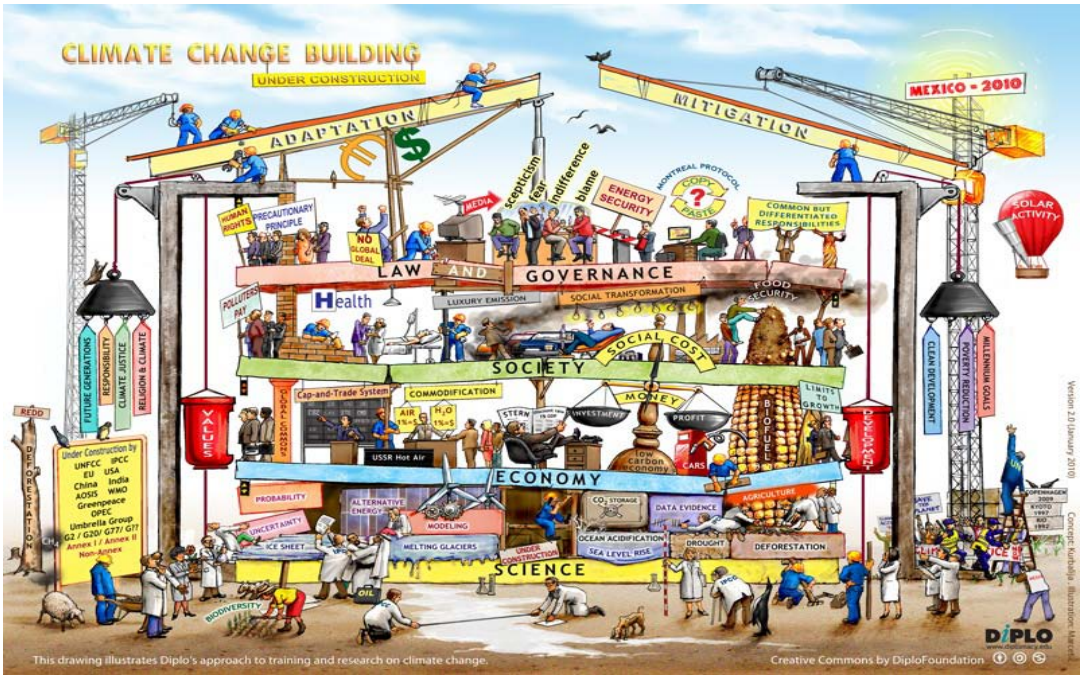

Figure 1: Climate change science is complex and can certainly be confusing (http://www.diplomacy.edu/climate/)

However, for the young people in our communities and classrooms who are learning about the planet, acquiring skills and insights into the complex socio-environmental and economic realities of the world, knowing the basics of climate science is imperative. Scientific information on climate change must be disseminated in a way that allow is to be broadly understood, including elements related to its environmental, social, economic and policy aspects to schools and universities around all continents. Students should have a chance to discuss the problems, barriers, challenges and chances and potentials related to climate change both in the local and regional level but also globally. This will raise awareness among secondary and university students on the complexity of matters related to climate change and the need for personal engagement and action.

Figure 2 For addressing the stakeholder challenges associated with climate change mitigation and adaptation an appropriate knowledge base is needed

Human-induced global change is really a symptom of outdated ways of thinking, worldviews, and ideologies that are not only unsustainable but threaten the very survivability of the human species and environmental systems we depend on. For centuries, people thought that earth processes were so large and powerful that nothing we could do would change them. This was a basic tenet of geological science: that human chronologies were insignificant compared with the vastness of geological time; that human activities were insignificant compared with the force of geological processes. And once they were, but no more. There are now so many of us cutting down so many trees and burning so many billions of tons of fossil fuels that we have indeed become geological agents. We have changed the chemistry of our atmosphere, causing sea level to rise, ice to melt, and climate to change. There is no reason to think otherwise. Discovering ways to encourage whole systems, holistic thinking and behaviour is perhaps the ultimate conundrum of this generation as we move to address the phenomenal challenges of the 21st century.

How to better teach students about climate change has been an issue of great concern among climatologists and also educators. In recent years educators' awareness of climate change has continuously improved. However, majority of countries haven't yet set up a systematic educational program on climate change. The topic is indeed complex because the Earth's systems are complex, and scientists themselves are not at all certain of the potential ramifications of our interference with these systems. Formidable from an educator's point of view is the intangibility of climate change: its global scale and seemingly slow progression make it a phenomenon that does not easily lend itself to classroom demonstration. And teachers and students who wish to take action on climate change find themselves up against the ingrained habits and attitudes of an industrial society created and powered by fossil fuels and supported by political inertia in establishing regulatory policies to curb greenhouse gas emissions.

It must be understood that climate science literacy is an ongoing process. Students are not expected to understand every detail about all of the fundamental climate science. Full comprehension of these interconnected concepts will require a systems-thinking approach, meaning the ability to understand complex interconnections among all of the components of the climate system. Moreover, as climate science progresses and as efforts to educate the people about climate’s influence on them and their influence on the climate system mature, public understanding will continue to grow.

But teaching about and taking action on climate change may not be as difficult as it seems. Teachers and students should explore some of the key questions related to climate change: What are its causes? What might we expect? What are governments doing about it? And, most important, what can schools and students do about it? In working with young people, teachers have a great many opportunities to address these vitally important questions. Many topics that would be part of a study of climate change are already part of most primary school curricula: these include, for example, technology topics such as energy systems; social studies topics such as political decision-making; or geography and science topics such as weather systems, photosynthesis and decomposition, and adaptations of plants and animals to specific habitats and climatic conditions. Moreover, many teachers and students are already engaged in activities that are helping to reduce their own and their schools' greenhouse gas emissions: planting trees near the school building, conserving energy and water, reducing waste, walking or cycling to school instead of driving. It is only a small step to incorporate discussion of climate change into these curricular areas and activities. Promoting climate literacy through informal science learning environments is important, as well.

Regarding climate change society has three options. First is mitigation, which means measures to reduce the pace & magnitude of the changes in global climate being caused by human activities. Examples of mitigation include reducing emissions of GHG, enhancing "sinks" for these gases, and "geoengineering" to counteract the warming effects of GHG. Second choice is adaptation, which means measures to reduce the adverse impacts on human well-being resulting from the changes in climate that do occur. Examples of adaptation include changing agricultural practices, strengthening defense against climate-related disease, and building more dams and dikes. Suffering the adverse impacts that are not avoided by either mitigation or adaptation is the third option. Mitigation and adaptation are both essential. Human-caused climate change is already occurring and is already dangerous. Adaptation efforts are already taking place and must be expanded. But adaptation becomes costlier and less effective as the magnitude of climate changes grows. The greater the amount of mitigation that can be achieved at affordable cost, the smaller the burdens placed on adaptation and the smaller the suffering.

3. Conclusions

Climate change is not just our grandchildren's problem or our children's problem. It is our problem. We and our predecessors caused it. We have the responsibility to address it. If not addressed with adequate wit, wisdom, and resources, the disruption of global climate will thwart societal aspirations everywhere. It will erode well-being where it now exists and it will prevent the attainment of well-being everywhere else. It will undermine any prospect for international peace and stability. The costs of addressing it will be far less than the costs of ignoring it. The countries and companies that take the lead in turning challenge to opportunity & cost to benefit will help themselves and help us all.
Education is a critical element in the response to the challenges of climate change. Climate is an ideal interdisciplinary theme for lifelong learning about the scientific process and the ways in which humans affect and are affected by the Earth's systems. This rich topic can be approached at many levels, from comparing the daily weather with long-term records to exploring abstract representations of climate in computer models to examining how climate change impacts human and ecosystem health. Learners of all ages can use data from a range of physical, chemical, biological, geographical, social, economic, and historical sources to explore the impacts of climate and potential adaptation and mitigation strategies.

Learning about climate change not only provides relevant literacy but it also allows empowering, enabling, motivating, informing, and educating the public around the technical, political, and social dimensions of climate change. In addition, unlike literacy which has a uni-directional connotation, engagement is as much about informing the public as it is about also informing experts and decision-makers. Communication should be viewed as a two-way process - with frames providing the context for dialogue - where experts and decision-makers seek input and learn from the public about preferences, needs, insights, and ideas relative to climate change solutions and policy options.

4. Literature

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