Advances in Natural and Technological Hazards Research

Jeanette L. Drake
Yekaterina Y. Kontar
Gwynne S. Rife *Editors*

New Trends in Earth-Science Outreach and Engagement

The Nature of Communication

Springer

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Advances in Natural and Technological Hazards Research

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To scientists everywhere whose discoveries create knowledge about Earth and about those who inhabit Earth … and to those in the field who communicate those discoveries by mastering the even more uncertain terrain of human interaction.

Foreword

In the field of ecology, **resilience** is defined as the capacity of an ecosystem to respond to a perturbation or disturbance by resisting damage and recovering quickly. If a disturbance forces the ecosystem to reach a threshold beyond which the ecosystem can recover and/or resist damage, the ecosystem can degrade, resulting in less desirable conditions for sustaining all forms of life (Peterson et al. 1998; Folke et al. 2004).

This definition of resilience provides useful context for understanding and addressing major global challenges that are rooted in the Earth sciences. The scientific community has rapidly advanced basic understanding and knowledge about climate change, natural and man-made disasters and hazards, and the availability of natural resources. This advanced understanding has provided insights into the resilience of Earth's ecosystem to natural hazards and disasters (floods, wind, severe weather, etc.), limitations on natural resources (water, energy, etc.), and the predicted impacts of anthropogenic climate change. The resulting picture is not encouraging.

Global population growth, continued destruction from severe weather and other disasters, impacts of climate change, and decreased availability of water, energy, and food needed to support a healthy society are all negatively impacting the resilience of Earth's ecosystem. Yet, governments around the world, along with the private sector and the public, seem unable to forge consensus on a path forward for addressing these issues. Novel approaches are needed to effectively apply science in solving real-world issues and in educating and communicating scientific knowledge in a way that is understandable and usable by the public, policy makers, and the private sector.

In *New Trends in Earth-Science Outreach and Engagement,* editors Jeanette L. Drake, Ph.D., Yekaterina Y. Kontar, and Gwynne S. Rife, Ph.D., have amassed a collection of innovative methods and approaches that can inform the debate about, and contribute to, potential solutions for addressing these worldwide threats. Earth and space scientists, social scientists, educators, and other key stakeholders can use this monograph to better inform and educate a variety of audiences and assist with evaluating policy solutions.

Those most interested in informal and formal education will find compelling examples for educating the broad public, using technology to increase understanding and motivate action, and for incorporating new teaching methods into science curriculums. Scientists and others interested in policy making will find a comprehensive overview of the policy environment along with a candid assessment of future levels of governmental funding of science. Those scientists who want to learn more about effectively communicating with non-science audiences will benefit from research on cultural cognition and message testing, as well as tools, resources, and training available through scientific societies and other organizations. Scientists interested in unique ways of applying their science to real-world problems will find successful examples to adapt and model in their own work.

During a time when the public and political landscapes have become polarized and scientific understanding about climate change, natural disasters, and natural resource limitations has become misconstrued, this monograph illustrates a way forward using concrete examples from the education, scientific, and not-for-profit sectors. All can benefit from the insights provided as well as apply and adapt these examples to fit their particular circumstances. Through concerted action at all levels, scientists and scientific societies can play a significantly greater role and exert considerable influence in assuring a resilient and healthy ecosystem on this planet that we call home.

Executive Director/CEO Christine McEntee
American Geophysical Union

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Preface

This monograph was spawned by two special sessions at the Fall Meeting of the American Geophysical Union (AGU) Dec. 3–7, 2012, in San Francisco. In preparation for the conference, we issued a call for new ideas in geoscience and environmental communication. The number of responses overwhelmed but did not surprise us given the context of the Union's reinvigorated strategic plan that cast the spotlight on communication when it held up as one of four key areas, *science and society*.

We saw in that positive response some of the *pent up enthusiasm* to which AGU outgoing president Michael J. McPhaden referred in his farewell address. In fact, communication has become a prominent theme as AGU has started adopting a more proactive approach to interacting with the public, the media, and policy makers about the importance of the study of Earth and its environment. McPhaden (2011) explained the *science and society* goal:

> I think you're going to see AGU become a more recognizable entity in the mind of the public and in the policy arena . . . We made a real conscious effort to be more outspoken, because what we do is so relevant to so many aspects of life and property in the United States and around the globe. Natural hazards are based in geophysical science. We want to make sure that the public and policy makers understand the power of that science to better their lives and livelihoods. So the vision in my mind is that AGU is going to be recognizable in the same way that, say, the American Medical Association is recognizable. When you read about the AMA, you know exactly what the source of that authority is and how much weight it carries. When you see AGU in the press, you'll recognize right away that this is the "go to" place for authoritative information on Earth and space science. ("AGU leadership reflects", pp. 308–309)

Indeed, that is the impetus behind this monograph: A more proactive approach to communicating with a variety of audiences about the importance of Earth and space science in everyday life.

The 2012 AGU Fall Meeting comprised more than 1,800 sessions devoted to geoscience. Barely 1 % of those sessions addressed how to communicate that science. The purpose of this monograph is to capture the best of that 1 % so that it might be more widely disseminated among the scientific community. We have selected 17 papers to feature in this monograph. Cumulatively, these works are impressive in their breadth and in their depth not only in terms of geophysics, which was expected, but also in terms of communication.

This monograph represents nearly 50 authors who are geophysical scientists, social scientists, educators, and professionals in the field. They are from universities and research institutes, government agencies, and corporations. They represent multiple disciplines, including geoscience, geoscience education, climate science education, climate science communication, and public policy. They come from across the United States and around the world.

Uses for the Book

This monograph is unique in that it provides:

- *A manual of geoscience communication for scientists, policymakers, and media*
- *An up-to-the-minute context of environmental hazards, new technologies, and the political landscape*
- *A work by geoscientists for geoscientists working alongside social and behavioral scientists and practitioners*
- *A work underpinned by key communication theories and interspersed with pragmatic solutions*
- *A work that crosses traditional boundaries: international, interdisciplinary, theoretical/applied*

Each of the book's editors brings a different perspective to this book: science policy and education, public relations and communication expertise, Earth science education and outreach—all with a passion for communicating about science policy and the environment.

Overview of the Book

The book comprises five units that focus on geoscience communication in terms of framing climate change, identifying the role of science in the conversation, maximizing new media and technologies, stemming the tide of science illiteracy, and organizing for resources and resiliency. Contributing authors have provided case studies and best practices at the intersection of geophysical and social and behavioral sciences.

Unit one introduces concepts that frame climate change understanding among scientists, media, commercial sector, and the general public. It delves into relevant communication theories of persuasion and inoculation.

Unit two highlights various roles scientists play in geoscience and climate science discussion. It also introduces roles of other society members from lawyers to policy makers in science discourse. This unit touches on narrative, relationship, and excellence communication theories.

Unit three emphasizes the importance of social media and emerging technologies in modern day science conversation. It also highlights the importance of nonstandard and afterschool education. The unit delves into communication areas of new media and media effects.

Unit four focuses on the importance of the expansion of STEM education beyond the usual merit. It also delves into diffusion and deliberation communication theories as well as controversy in classroom and ICE.

Unit five introduces new concepts in climate change and natural hazards resilience and adaptation techniques and resource availability. The unit also delves into the shift from aversion to adaptation.

Our hope is the book will help to promote new and effective approaches in communication processes necessary in bridging the gap between geoscience, global environmental change knowledge, public opinion, and policy.

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Reference

"AGU leadership reflects," (2011) Eos 92(37):7–8. 13 September 2011, pp 308–309

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We would like to thank the American Geophysical Union (AGU) for understanding the importance of science education, public affairs and communication, and policy for the future of our planet. Due to the support of scientific organizations such as the AGU and collaboration among scientists, policy makers, educators, and the media, the gap between science and society can be bridged.

We also would like to thank all of the participating authors and reviewers, and encourage them in their future endeavors in promoting science outreach and engagement. This book comprises a wealth of experience and expertise and represents remarkable work being done every day in the lab, in the field, in the classroom, and in the spotlight.

Finally, we extend special appreciation to everyone at Springer Publishers, without whom this book would not be possible.

The University of Findlay — Jeanette L. Drake
University of Alaska-Fairbanks — Yekaterina Y. Kontar
The University of Findlay — Gwynne S. Rife

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Erna Akuginow (B.A., New York University, 1971) is a former producer for CBS Television, and was a writer, producer, and director for the award-winning PBS/Channel 4 (UK) co-production, *Childhood*. She previously worked with noted environmentalist and microbiologist Rene Dubos, astronomer Carl Sagan, and with Adrian Malone, executive producer of the BBC's *Ascent of Man*. Along with Haines-Stiles, she was Co-Founder of the LIVE FROM… series of electronic field trips to scientific frontiers, PBS's longest running series of interactive science programming. She is Executive Producer of *Earth: The Operators' Manual*, a series of PBS specials on climate change and clean energy, funded by NSF, that premiered in 2011 and aired back to back on Earth Day 2012. With expertise in visual effects and animation, Akuginow's other works include specials on NASA's Mars missions including *What Went Right*, and live programs for CNN/Turner Broadcasting on the *Voyager* spacecraft's encounter with Neptune.

Richard B. Alley (Ph.D., University of Wisconsin-Madison, 1987) is the Evan Pugh Professor of Geosciences at the Pennsylvania State University. Alley has authored more than 170 refereed scientific publications about the relationship between Earth's cryosphere and global climate change. He was awarded IGS's Seligman Crystal in 2005 "for his prodigious contribution to our understanding of the stability of the ice sheets and glaciers of Antarctica and Greenland, and of erosion and sedimentation by this moving ice." In 2005, Alley was the first recipient of the Louis Agassiz Medal for his "outstanding and sustained contribution to glaciology and for his effective communication of important scientific issues in the public policy arena." Alley has been a contributor to the United Nations Intergovernmental Panel on Climate Change, which shared the 2007 Nobel Prize with Al Gore. Recently, he hosted PBS's *Earth: The Operators' Manual* and developed a Coursera MOOC on energy and climate.

Minda Berbeco (Ph.D., Tufts University, 2011) is the programs and policy director at the National Center for Science Education and a visiting scholar at the University of California Museum of Paleontology. After receiving a doctorate in biology, she worked as a postdoctoral scholar at the University of California, Davis studying biogeochemical cycles and climate change issues.

Richard Bernknopf is a Research Professor at the University of New Mexico. Before joining the faculty at UNM, Dr. Bernknopf was an economist with the USGS for more than 38 years. Dr. Bernknopf's research focuses on the demonstration of the value to society of natural science information including earth observation and the translation of that information into a form compatible with decision-making processes. Currently he is associated with the Science Impact Laboratory for Policy and Economics at the University of New Mexico and the Wharton Geospatial Initiative at the University of Pennsylvania.

Scyller J. Borglum (M.T.S., Duke Divinity School, 2003) attended Pacific Lutheran University where she received a bachelor's degree in business with a focus on international business and Norwegian language. While on a Fulbright Scholarship at the University of Oslo in Norway, she studied sustainable development via international business. She returned to the United States and received her master's degree in theology with a focus on Biblical ecology. After 7 years in sales, Borglum went to Montana Tech in her home state to study natural fractures and pressure dependent permeability in the Bakken formation. She will receive a Master of Science in petroleum engineering in 2014.

Bente Lilja Bye (Cand.Sc., University of Oslo, 1990) is an astrophysicist and Earth science expert living in Norway. She runs her own company Bente Lilja Bye/BLB doing research, consulting, and scientific outreach. Previously, she worked as research director at the Norwegian Mapping Authority. She also was responsible for scientific and strategic work for the Geodetic Institute, where she got involved in work related to understanding the dynamics of planet Earth, manifested in phenomena such as climate change and natural disasters. In her capacity as research director for the Norwegian Mapping Authority, Bye got involved in outreach and user linkage to a wide range of audiences. She planned and led a combined science and outreach expedition to China and Tibet called Geodetic Journey in 2007 and has since developed a presence in social media as a science writer. She has been involved in Group of Earth Observations since 2004.

Alan C. Chan (M.S., Cornell University, 2002) joined Sonoma Technology Inc (STI) as a meteorologist in 2002, and has served as manager of forecasting and public outreach operations since 2008. Throughout the last decade, he has enjoyed combining his passion for weather with his knowledge of air quality to produce thousands of air quality forecasts for over a dozen US cities. Chan applies his project management skills and experience to oversee the operations of the nationwide AirNow program. As a native of Hong Kong, he has been keen to expand the AirNow system beyond North America and, over the past 6 years, his efforts to build a relationship with the Chinese team were instrumental in launching AirNow-International in Shanghai during the 2010 World Expo. Chan also holds a bachelor's in geography with distinction and highest honors from Boston University. While studying meteorology at Cornell, he earned the Cornell Outstanding Teaching Assistant Award.

Arlene R. Courtney (Ph.D., Texas A&M University, 1980) is a Professor at Western Oregon University, where she has taught in the Department of Chemistry for the past 25 years. Among the courses that she teaches are courses in environmental chemistry and energy resources at both the upper division science major and non-science major levels. Her research interests have been quite varied and have included the use of organozirconium reagents in organic synthesis and bioremediation of organic compounds in the environment. Recent projects involve the development of multimedia documentaries about energy resources and have taken her to Iceland, Nova Scotia, Hawaii, New Zealand, and Australia. For the last 15 years, she has explored the use of video as a learning vehicle in the university classroom both as a tool for delivering instructor-generated content for the students and, more recently, by incorporating student video creation into the curriculum.

Danny Cullenward (M.S., Stanford University, 2007) is a joint J.D./Ph.D. candidate at Stanford Law School and in the Emmett Interdisciplinary Program in Environment & Resources (E-IPER) at Stanford University. His dissertation research integrates insights from energy economics and law to develop effective, science-based climate policy at the state and federal levels. Working with the Stanford Environmental Law Clinic, Cullenward focuses on the evolution of California's climate policy regime, reinforcing the application of the best available science through litigation, public comments, and regulatory development. His work is supported by a David and Lucile Packard Foundation Stanford Graduate Fellowship.

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Jeanette L. Drake (Ph.D., Bowling Green State University, 2004) is an Associate Professor at The University of Findlay in Ohio, USA, where she researches environmental communication. She seeks to understand the influence of framing on public dialogue about health and the environment and subsequently on public policy. She consults nonprofits, has served on the board of directors for the Cuyahoga Valley Countryside Conservancy, and often integrates *sustainability* into the classroom. Accredited in public relations, her work has earned awards from the Public Relations Society of America, where she is past president of two chapters and, in 2008, was elected to the College of Fellows. Drake has authored hundreds of articles and is frequently invited to speak and conduct workshops throughout the country. She is the founding director of the public relations master's program at Kent State University and, as a visiting faculty member in 2010 at the University of Social Sciences and Humanities in Ho Chi Minh City, Vietnam, she developed a certificate program in public relations. In addition to her doctorate in communication studies, she holds a bachelor's degree in social and behavioral sciences, and a master's degree in journalism from The Ohio State University.

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Gretchen Goldman (Ph.D., Georgia Institute of Technology, 2011) is an analyst in the Center for Science and Democracy at the Union of Concerned Scientists. She researches influences and interference in how science informs policymaking. She came to UCS from the Georgia Institute of Technology where she was a postdoctoral research fellow working on statistical modeling of urban air pollution for use in epidemiologic studies of acute human health effects. Her recent work has focused on corporate influence on climate science, federal scientists' freedom of speech rights, and public right-to-know in science-based policies. While at GT, she was named a Georgia Tech Presidential Scholar and earned the 2011 Outstanding Doctorate Candidate Award for Environmental Engineering. She also holds a master's degree in environmental engineering from Georgia Tech and a bachelor's in atmospheric science from Cornell University.

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Glenn C. Miller (Ph.D., University of California at Davis, 1977) is a Professor of Environmental and Resource Sciences at the University of Nevada, Reno. He is also presently Director of the Graduate Program in Environmental Sciences and Health at UNR. He has a B.S. in Chemistry from the University of California, Santa Barbara (1972) and a Ph.D. in Agricultural and Environmental Chemistry (1977) from the University of California at Davis. Current areas of research focus on Nevada mining issues, including precious metals pit water quality, acid mine remediation using anaerobic sulfate reducing system and reducing conflict in mine permitting.

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Gilla Simon (Ph.D., Ecole Normale Supérieure, 1997) is the deputy director for the Museum Mensch und Natur, Munich, where she has been responsible for developing exhibitions and educational programs since 2007. Previously, she worked as a curator at the Mineralogische Staatssammlung Munich. Simon earned her master's (1994) and doctoral (1997) degrees in geology and mineralogy at Christian Albrechts University of Kiel, Germany, and at Ecole Normale Supérieure Paris, France, and completed post-doctoral studies at University of Potsdam.

Mary Ann Stewart is principal for Stewart Engineering LLC, formed in 2002 to provide business development, research and analysis services to the geospatial community. Geospatial projects include Return on Investment (ROI) case studies funded by the US Federal Geographic Data Committee (FGDC) and Canadian GeoConnections. Other business activities include consulting services in the area of data, business development for small firms and market research for the utility information technology market. Before starting a small business, Ms. Stewart was manager of data acquisition for an investor-owned gas and electric utility, UtiliCorp/Aquila.

Kristan Uhlenbrock (M.S., University of South Florida, 2009) joined the American Geophysical Union in July 2011. At AGU, she works to bridge public policy with the scientific community, communicate the importance of science to our nation's leaders, and train scientists on how to better communicate their work. Prior to joining AGU, Uhlenbrock worked at the Environmental Protection Agency in the Ocean and Coastal Protection Division and the White House Council on Environmental Quality to implement, educate, and engage stakeholders on the National Ocean Policy. At the University of South Florida, College of Marine Science, Uhlenbrock studied nutrient distributions and impacts on coastal estuarine systems and their role in sustaining harmful algal blooms in the Gulf of Mexico. She received a bachelor's degree in chemistry from the University of South Florida. Uhlenbrock has been actively engaged in the science policy field for over 8 years with interest in sustainable ocean policy.

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Philip D. Wade (M.A., San Diego State University, 1991) is a senior lecturer in the Department of Earth and Physical Sciences at Western Oregon University. He holds degrees from San Diego State University in engineering geology and science education. He has taught in K-12 schools, and for the past 16 years taught geosciences and science education courses at the university level. Professional experiences include serving on the Oregon Department of Education assessment panel, consultant work for the Education Programs Office at Lawrence Livermore National Lab, and member of the Education Board of A.C. Gilbert Discovery Village. His research focuses primarily on how to enhance and assess students' conceptions of the nature of science and how project-based curriculum can enhance student learning.

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Part I
Framing Climate Change

Chapter 1
Assessing Corporate Influence on Climate Change Dialogue

Gretchen Goldman, Francesca Grifo*, Paul Rogerson*, and Benjamin L. Gutman*

Communication on climate change has stalled in the United States. Many factors are to blame, including the complexity of the science, the influence of disparate actors, and the politicization and polarization of the issue. Much work has been done to characterize and address the challenge of communicating climate change to the public (Kahan et al. 2011; Weber and Stern 2011). Studies have demonstrated the presence of misinformation in the public dialogue, even after retracted or refuted, can inhibit individuals' abilities to recognize correct information (Ecker et al. 2011; Lewandowsky et al. 2012). Evidence shows climate change has fallen victim to this phenomenon (Cook and Lewandowsky 2011; Jacques and Dunlap 2008).

One source of mixed messaging on climate change is the private sector. Corporate messages on climate change in the public sphere have differed widely: From support for international climate negotiations and green marketing campaigns to expressions of doubt about climate science and organized denial campaigns (Union of Concerned Scientists [UCS] 2012b). Several large American companies have spoken out in favor of climate science and science-based policy (Kolk and Levy 2001). Again, we point to the poll conducted in 2000 that indicated 75 % of Fortune 5,000 executives believed global warming to be a serious problem (Carpenter 2001). Yet, at the same time, pervasive corporate-funded campaigns have developed to spread misinformation about climate change and block policies addressing it (Dunlap and McCright 2011; Levy and Egan 2003).

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Such dissimilar corporate messages were analyzed in order to determine which have aligned with climate science. In addition, sample companies are identified as consistent or inconsistent in their climate change-related actions. In this chapter, we provide background information, detail the methodology, present and discuss the findings, and recommend ways to hold companies accountable for their statements on climate change.

1.1 Background

Corporations in the United States have always taken part in national discussions on laws and regulations that might affect their industry. In our democracy, this is a company's right. However, when new scientific data reveal a threat to public health, safety, or the environment, factions of the affected industries often oppose calls for regulation by attacking the science on which discussions are based (UCS 2012a).

Corporate interests have questioned the scientific consensus around an issue, and they have countered established findings by promoting their own studies—conducted with flawed methodologies—that lead to a predetermined outcome. They may pay seemingly independent scientists to further undermine the original findings (Michaels 2008; UCS 2008, 2012a). Moreover, industry players have been known to intimidate or openly attack scientific researchers, to skew analyses of the costs and benefits of proposed regulations, or to undermine the regulatory process itself (Mann 2012; McGarity and Wagner 2008; UCS 2012a).

This multipronged strategy was first widely exposed in the now infamous case of the tobacco industry's efforts to delay regulation of cigarettes by spreading doubt about the link between smoking and lung cancer. But these tactics also have been observed time and time again in debates over other science-based efforts to protect the American public (Michaels 2008).

For example, despite substantial scientific evidence that sulfur emissions from coal-fired power plants were harming lakes and forests in the Eastern United States as a result of acid rain (NRC 1981), utility companies, the Reagan Administration, and the business press emphasized uncertainties in the science and played up the potential costs of reducing emissions (Brown 1986). These efforts delayed serious action toward solving the problem until the passage of the Clean Air Act Amendments of 1990 (Christopher et al. 2011).

In the case of asbestos exposure, companies fought for decades to deny growing scientific evidence of the health risks, such as asbestosis and asbestos-related cancers (Michaels 2008). As late as 1991, the asbestos industry successfully challenged a rule that would have resulted in a partial ban on new asbestos products, convincing a judge that the U.S. Environmental Protection Agency (EPA) had "presented insufficient evidence" of the dangers of asbestos (Environmental Protection Agency [EPA] 2010).

Similarly, when scientific evidence mounted that linked DDT and similar pesticides to the devastation of bird and other wildlife populations, as widely publicized by biologist Rachel Carson in her book *Silent Spring*, chemical companies—including Monsanto, Velsicol Chemical, and American Cyanamid—attacked Carson as a "hysterical woman" unqualified to write a book about pesticides (Matthiessen 1999).

The influence of corporations has become more visible and pervasive in recent years (UCS 2012a). Industry interference has been observed in a variety of venues where science is used to inform federal policy, ranging from congressional interference in Food and Drug Administration approval of medical devices (UCS 2009) to the politically motivated blocking of a science-based national air quality standard for ground-level ozone proposed by the EPA (Broder 2011).

After attacking the science, many companies warn that regulation of their products or byproducts will severely damage their businesses. Yet political recognition of a health or environmental problem and its subsequent responsible regulation has consistently proven to mitigate the danger at hand without devastating economic impact to industry (Burnett and Hansen 2008; Meyer 1995).

A similar pattern of industry attacks on science and science-based regulations has occurred with climate change. Because numerous and wide-ranging economic sectors have stakes in the outcome of climate policy debates, diverse industrial actors have engaged in attacks on climate science (Levy and Egan 2003). These powerful corporations have been tremendously influential in dictating how the public understands climate science and how the national discussion on climate policy has progressed—or *not* progressed.

Industry has been able to exert this influence through time-tested public relations strategies and tactics, including: exaggerating the uncertainty associated with climate change while ignoring what is known; funding contrarian scientists and think tanks engaged in spreading misinformation and blocking policy; and contributing to politicians who proclaim they do not believe in the science of global warming. This highly orchestrated climate change denial machine has been well documented (Begley et al. 2007; Dunlap and McCright 2011; Oreskes and Conway 2010).

Yet there is another side to the story. Despite the increased hostility toward climate science and policy by some corporate players, other companies are choosing a different path. Beginning in the early 2000s, when international climate negotiations had significant support and climate legislation seemed more likely to pass, several large American companies spoke out in favor of climate science and science-based policy (Kolk and Levy 2001; Layzer 2007). Many companies took direct actions by calling for comprehensive legislation to address climate change, launching initiatives to lower their carbon footprints, and publicly dissociating themselves from groups that undermine climate science. A poll conducted in 2000 indicated that 75 % of Fortune 5,000 executives believed global warming to be a serious problem (Carpenter 2001).

But although these bold expressions of support for climate action date from more than a decade ago, and although much stronger scientific evidence reinforces the need for such support, much of the corporate concern about climate change is being drowned out by a resurgence of attacks on climate science (Mann 2012). Still, a small contingent of companies remains vocally supportive of science-based climate policy.

Further complicating corporate engagement in climate change are two phenomena—heightened consumer demand for environmentally friendly products and services, and consumers' increasing calls for corporate social responsibility (CSR)—which, together, have led many companies to rethink their business strategies (Vogel 2005). While in some cases this has helped create a context in which companies can advocate for climate action, it also has opened a door to "greenwashing"—in which companies use public-relations campaigns to make unsubstantiated claims regarding their environmental stewardship (Dahl 2010).

Climate change has fallen victim to many such corporate communications, making it more difficult for policy makers and the public to determine who is actually committed to climate action (earnestly "walking the walk") and who has simply learned to speak the language (just "talking the talk"). The latter strategy allows companies to maintain a public image of climate consciousness while behind the scenes undermining climate science and policy in powerful ways.

1.2 Methods

Communication activities from 28 U.S.-based companies in the Standard and Poor (S&P) 500 were analyzed to determine which of these corporate messages have aligned with climate science. Guided by the methodology below and further detailed in previous work (UCS 2012b). The companies were identified as consistent or inconsistent in actions related to climate change.

1.2.1 Sample Selection

To obtain a manageable study scope, actions of 28 companies were scrutinized (see Table 1.1). Companies were selected on the basis of their engagement in one of the following policy proposals.

1. They commented publicly on the Environmental Protection Agency's (EPA) Endangerment and Cause or Contribute Findings for Greenhouse Gases under Section 202(a) of the Clean Air Act ("EPA Endangerment Finding") (EPA 2009).
2. They contributed to either the pro- or anti-Proposition 23 campaigns during the 2010 California election. "Prop 23," if approved, would have suspended "implementation of air pollution control law (AB 32) requiring major sources of emissions to report and reduce greenhouse emissions that cause global warming, until unemployment drops to 5.5 % or less for [a] full year." (California Secretary of State 2010)

Both forums influenced public climate discussions on the national stage in 2009 and 2010.

The EPA Endangerment Finding was a legally mandated and formal determination, made in draft form in April 2009 after a 2-year scientific review, that carbon

Table 1.1 Company selection criteria

Company	Participated in EPA Endangerment Finding	Participated in California Prop. 23
Chesapeake Energy Corporation	✔	
ConocoPhillips	✔	
Denbury Resources Inc.	✔	
Exxon Mobil Corporation	✔	
Marathon Oil Corporation	✔	✔
Murphy Oil Corporation	✔	
Occidental Petroleum Corporation	✔	✔
Peabody Energy Corporation	✔	
Tesoro Corporation		✔
Valero Energy Corporation	✔	✔
Ameren Corporation	✔	✔
AES Corporation		✔
DTE Energy Company	✔	✔
FirstEnergy Corporation	✔	
NRG Energy, Inc.	✔	
NextEra Energy, Inc.		✔
Progress Energy, Inc.	✔	
Sempra Energy		✔
TECO Energy, Inc.	✔	
Xcel Energy Inc.	✔	
Boeing Company	✔	
Caterpillar Inc.	✔	✔
General Electric Company	✔	✔
Waste Management, Inc.	✔	
Alcoa Inc.	✔	
FMC Corporation	✔	
Applied Materials, Inc.		✔
NIKE, Inc.	✔	✔

Color Key by Stock Market Sector:

Energy · Utilities · Industrials · Materials · Consumer Discretionary · Information Technology

*Note***.** Twenty-eight publicly traded American companies participated in the public discussion surrounding the EPA's Endangerment Finding, California's Proposition 23, or both dioxide and five other greenhouse gases are pollutants that threaten public health and welfare. Since the Clean Air Act mandates that the EPA regulate such pollutants, the Endangerment Finding set the EPA on a course, particularly in the absence of any other federal-level policy, to implement the only federal carbon-regulation policy in the United States.

After the draft Endangerment Finding was announced, the EPA accepted public comments for 60 days before making a final determination in December 2009. Among more than 380,000 total submissions (www.regulations.gov, docket EPA-HQ-OAR-2010-0171) were comments submitted by 23 members of the S&P 500, either directly or through trade groups and coalitions of which the companies were prominent members.

Prop 23, the other public venue in which corporate participation served as a criterion for this study's company selection process, was an attempt to prevent implementation of a pollution control law (AB 32), previously passed by California's legislature, that required companies to report their global warming emissions and begin to reduce them. Fourteen S&P 500 companies contributed money either to support or oppose Prop 23. Many also commented publicly on the EPA Endangerment Finding.

Among the 23 companies commenting on the EPA docket (directly or as prominent members of coalitions) and the 14 companies contributing to campaigns for or against Prop 23, a total of 28 S&P 500 companies had chosen to take a public stance on climate issues. To assure that companies were not passively participating, only those that had commented or donated independently in their own name at least once, or had done so as a member of a coalition at least twice, were included.

The 28 companies came from 6 different stock market sectors: Energy, Utilities, Industrials, Information Technology, Consumer Discretionary, and Materials (see Table 1.1).

1.2.2 Data Sources

To evaluate how and to what degree each company in the sample engaged in the climate science and policy dialogue, a broad range of communication media were assessed, with particular attention focused on the audiences for which each is directed (see Fig. 1.1). Published documents comprised a company's website, annual report, CSR or environmental report, press releases, executive statements and speeches, earnings calls, public comments to EPA, SEC Form 10-K, Internal Revenue Service Form 990, and congressional testimony. Recorded activities included political contributions, lobbying expenditures, trade and business association membership, and engagement with think tanks and other outside organizations.

After conducting our research, we invited company executives to respond to questions and discuss in interviews their climate positions. We hired an independent professional interviewer and drafted the interview protocol. We sent letters to executives and public affairs representatives at each of our sample companies, introducing our project and asking if they would be willing to share their thoughts regarding

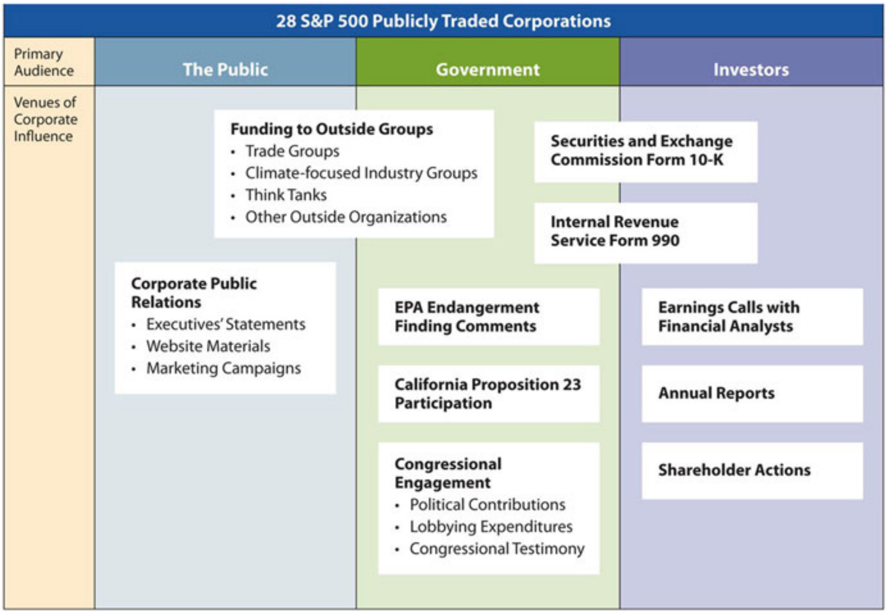

Fig. 1.1 Scope of research

their company's positions on issues surrounding climate change. Six companies (ConocoPhillips, Denbury Resources, Exxon Mobil, NRG Energy, TECO Energy, and Waste Management) accepted our interview request; we interviewed executives at each of those companies in the summer of 2011.

The size of the companies in our sample, as expressed by their market capitalization (calculated by multiplying share price by the number of shares outstanding), ranged from just over $3 billion to more than $400 billion when researched July 20, 2011 (YCharts n.d). The largest, Exxon Mobil Corporation, at $414 billion was more than twice as large as the next-largest, General Electric Company, valued at $197 billion. The median market capitalization was $16 billion. About a third of the companies had a market capitalization of less than $10 billion. The smallest, Tesoro Corporation, weighed in at $3.41 billion.

The majority of companies analyzed for this report (17 of them) were large-sized corporations with market capitalizations valued at $10 billion–$100 billion (see Fig. 1.1). Nearly one-third (eight) was mid-cap, valued at $1 billion–$10 billion. Three companies were in the mega-cap category, valued at over $100 billion. Most sample companies came from the Energy and Utilities sectors, with more than one-third of the companies in each of these two sectors.

The study period was predominantly 2008–2010, when climate legislation in the United States was most prominent in national discussions; however, to get a broader picture of corporate engagement, some areas of scrutiny drew from longer time periods, ranging from 2002 at the earliest.

1.2.3 Use of Indirect Communication Actions

In addition to scrutinizing companies' explicit statements, we also examined communication via acts taken to influence the climate debate, including affiliations with outside organizations, political contributions, and lobbying expenditures. Important caveats must be considered when analyzing such data. Although it is informative to examine these actions, we note that we cannot link them to climate change-related activities specifically. Without greater transparency in corporate affairs and government operations, we cannot isolate the particular issues on which companies lobbied, nor can we determine motivations for contributions to politicians and outside organizations. Our results thus can only highlight companies that have supported organizations that work on climate science or policy; we cannot claim that their corporate contributions were allocated to climate-related work specifically. Corporations take indirect actions related to climate change through membership in, board seats on, and contributions to industry trade groups, think tanks, and other outside organizations that are actively involved in issues of climate science and policy.

To identify companies, think tanks, and other organizations that misrepresented climate science in their statements or actions, we examined materials associated with their names and looked for statements therein about climate change that misrepresented the scientific consensus on climate change by way of

- emphasizing the unknowns about how human actions may affect the climate system while ignoring what is known;
- repeating untruthful claims about climate change science;
- manufacturing bogus scientific claims by such strategies as organizing dubious scientific conferences and paying for scientists to produce criticisms of mainstream climate science; and
- widely publishing climate-science claims that have not been subjected to peer review. (Adapted from Brown 2012)

Companies and outside organizations with statements affiliated with their name that had any of the above four characteristics were considered, for the purposes of this report, to be misrepresenting climate science.

1.3 Results

Companies span a wide range in their representations of climate change, both in terms of their engagement on climate science and their involvement in climate policy discussions. The public statements of some companies are consistent with their actions in supporting science-based climate policy and supportive policy makers. At the other end of the spectrum are companies that have taken many steps to inhibit science-based climate policy or misrepresent climate science.

1.3.1 Where Companies Stand on Climate Change

Many companies in our sample fell between the extremes, supporting climate science and policy in some venues and opposing them in others. This inconsistency contributes to misunderstandings among policy makers and the public of the state of climate science. Figure 1.2 identifies company statements and actions that were either in support of or in opposition to climate science and policy, and we make a distinction between corporate public relations (including executives' statements, marketing campaigns, and company websites) and less visible corporate actions (including comments on federal policy, government forms, and the funding of think tanks and other outside organizations). This distinction allows comparison of company behavior in front of two different audiences: the general public and decision makers.

Company statements and actions are considered "pro-climate" (blue) if they aligned with climate science or supported the implementation of science-based climate policies. Statements and actions are identified as "anti-climate" (brown) if they conflicted with the scientific consensus on climate change or otherwise inhibited progress toward developing and implementing science-based climate policies. The following key indicates the statements and actions for which companies received a "+1" or a "−1" for their statements (Corporate Public Relations) score or their actions (Corporate Actions) score.

All 28 of the companies in our sample utilized multiple venues to engage in discussions on climate change with different audiences, including the government, shareholders, and the public. In terms of policy, all but three of the companies in our sample made statements about the negative implications that climate change-related regulation could have for their business operations. Two companies—NRG Energy and General Electric—stated that climate regulations would have a *positive* impact on their businesses, and we found no statement from Boeing Company on climate regulation impact. Almost half of the companies (12 of 28) acknowledged, in at least one public venue, the potential dangers posed by the impacts of climate change itself (as opposed to impacts of regulation).

In general, we found a relationship between company actions and company statements. Companies that take more "anti-climate actions" are also more likely to have a more anti-climate speech position, either by making misleading statements or failing to make positive ones. Largely, the statements and actions of companies aligned with their expected position, given company sector and perceived financial interests. Both energy producers and utility companies have a vested interest in climate policy, as it can significantly affect their businesses, but they took different positions on climate science and policy, depending on their specific portfolio. For example, some utility companies in our sample—including NRG Energy, AES, and NextEra Energy—have taken many actions in support of climate science and science-based policy, including endorsements of the EPA Endangerment Finding, acknowledgments of climate-related risks to business, and public announcements of their carbon mitigation efforts. These companies have diverse portfolios that include

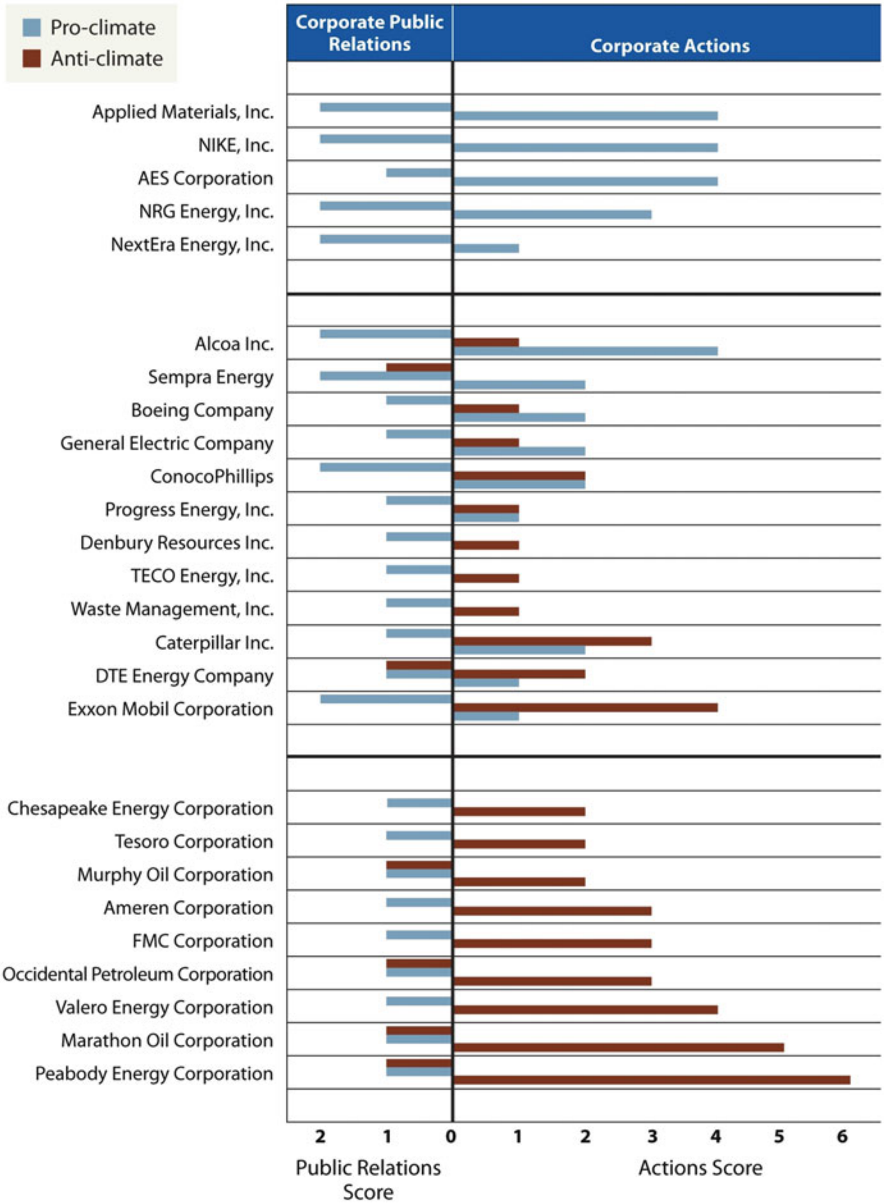

Fig. 1.2 Summary of corporate statements and actions on climate science and policy, which quantifies the statements and actions taken by companies across multiple venues, allows us to categorize company behavior on climate science and science-based policy. FirstEnergy Corporation and Xcel Energy Inc. are not included in this figure because their corporate actions on climate change were of insufficient number for categorization

	Supporting Climate Science and Legislation +1	Opposing Climate Science and Legislation -1
Corporate Public Relations	Acknowledges the scientific consensus on climate change OR expresses concern about the impacts of climate change	Misrepresents climate science
	Expresses commitment to taking voluntary mitigation actions	Does not express commitment to voluntary mitigation actions
Corporate Actions	Endorses specific climate change legislation or EPA action in EPA Endangerment Finding comments or SEC Form 10-K	Misrepresents climate science in EPA Endangerment Finding comments or SEC Form 10-K
	Endorses specific climate change legislation in venue other than EPA Endangerment Finding comments	Opposes specific climate change legislation in venue other than EPA Endangerment Finding comments
	Donates to the No on Prop. 23 campaign in California, 2010	Donates to the Yes on Prop. 23 campaign in California, 2010
	Funds think tanks or groups that support climate science or legislation	Funds think tanks or groups that undermine climate science or oppose legislation
	Contributes to "pro-climate" members of Congress by over 2:1 ratio	Contributes to "anti-climate" members of Congress by over 2:1 ratio

Fig. 1.2 (continued)

both fossil fuels and renewables. By contrast, some energy sector companies in our sample that predominantly focus on fossil fuel production, including Peabody Energy, Valero Energy, and Marathon Oil, have predominantly made statements—through their marketing campaigns, executives' public statements, congressional testimony, and EPA Endangerment Finding comments—that undermine established climate science and oppose carbon emissions standards.

Some companies in non-energy-based sectors also chose to actively engage in discussions around climate change. Nike, a consumer products manufacturer, and Alcoa, an aluminum producer, took many actions in support of science-based climate policies, while FMC, a chemical manufacturer, made statements misrepresenting climate science and opposing climate policy efforts.

1.3.2 Companies with Contradictory Actions on Climate Change

Fourteen companies were inconsistent in regard to their statements about climate change. While all companies in our sample stated they were taking voluntary internal action to reduce carbon emissions, half of them also misrepresented some element of established climate science in their public communications. These companies included Ameren, Chesapeake Energy, ConocoPhillips, DTE Energy, Exxon Mobil, FMC, Marathon Oil, Murphy Oil, Occidental Petroleum, Peabody Energy, Progress Energy, TECO Energy, Valero Energy, and Waste Management.

Figure 1.3 illustrates venues where specific companies acknowledged the scientific consensus on climate change or committed to addressing the challenge, and we

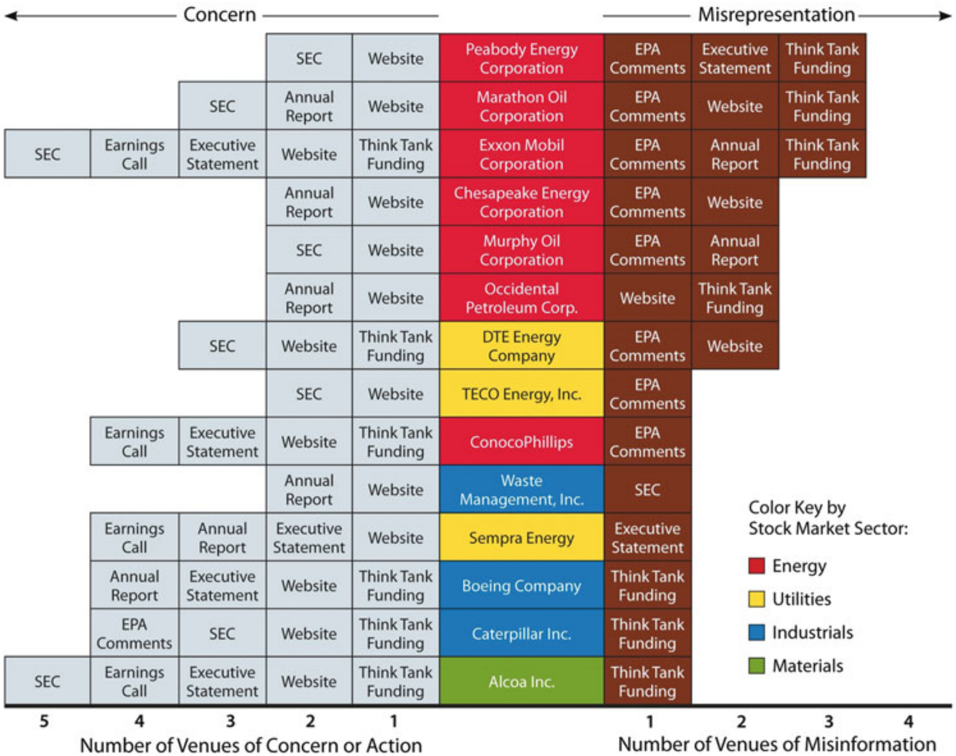

Fig. 1.3 Venues where contradictory companies express concern about climate change or misrepresent climate science. Listing only those companies in our sample that misrepresented climate science in at least one of their actions, venues of climate misinformation are compared with venues where these same companies expressed commitment or concern about climate change or stated that they were taking internal actions to deal with climate change. Here, "Annual Report" refers to a company's annual report to company investors, "SEC" refers to a company's annual Form 10-K filing with the U.S. Securities and Exchange Commission, and "Think Tank Funding" refers to a company's contributions to the think tanks and other outside groups that do significant work on climate change

contrast these expressions with venues where the same companies misrepresented established climate science. These results indicate that companies are more likely to express commitment or concern about climate change in communication messages directed at the general public, such as their corporate websites; and that companies are more likely to misrepresent climate science in one of two places: (a) in communication messages directed at the federal government, such as corporate comments in response to the EPA Endangerment Finding and (b) through their funding of outside organizations who misrepresent climate science in their work.

This latter finding—companies who misrepresent climate science tend to fund third-party organizations to do so—suggests that companies may be choosing to dissociate these messages from their company name. Companies fund think tanks, trade associations and other organizations for a variety of reasons, including representation of trade interests, interest in public policy issues, and philanthropy. However, some of these groups take starkly anti-science positions on climate change and work aggressively to challenge climate science and science-based climate policies. For example, both the U.S. Chamber of Commerce and the National Association of Manufacturers (NAM) have actively fought against science-based climate policy (NAM 2009; U.S. Chamber of Commerce 2009).

A significant lack of transparency exists with respect to corporations' support of outside organizations. When companies donate to outside organizations through their corporate foundations, they are legally required to disclose the recipient, amount, and purpose of each grant on their annual IRS Form 990. However, companies can circumvent this requirement by giving directly, rather than through their philanthropic arms, to outside groups (Kahn 1997) and it has been estimated that only 31 % of all corporate donations are made through corporate foundations (Giving USA Foundation 2011).

Congress and company shareholders alike have attempted to require companies to disclose their corporate giving. Several corporations, including General Electric, have received shareholder proposals requesting a list of charitable contributions (Tonello 2011). In 2009, shareholders of Waste Management proposed greater disclosure of political contributions so that positions taken by supported groups—Waste Management has a seat on the board of the NAM, for example—would not run counter to the company's stated goal of corporate leadership on climate change. The resolution read, "Without disclosure, it is impossible for shareholders to know whether Waste Management payments to [the] NAM are used for the group's political activities, including those opposing climate change legislation" (IBT General Fund 2010).

1.4 Conclusion

Companies play a large role in steering the direction of the public dialogue around climate change. Half of the companies in our sample misrepresented climate science in public communications during the study period. Companies were more likely to express concern about climate change or express commitment to taking mitigation actions when they are speaking with public-facing audiences, such as in statements made by their executives and on their website materials. And companies were more likely to misrepresent climate science in venues directed at the government, such as in their public comments on policy proposal or statements to the Securities and Exchange Commission (SEC), or through their indirect actions, such as the funding of think tanks or trade associations that misrepresent climate science in their materials. Some of these companies inject confusion into the public discourse on climate change by taking contradictory actions in venues with different audiences. The influence of these corporations and the resulting delay and defeat of policy efforts to address climate change have huge implications for government, the economy, peoples' well-being, and the planet.

The scope of this research has been limited by a lack of transparency in corporate political activities. This lack of transparency enables companies to be contradictory in their statements and actions on climate change by inhibiting their accountability. Publicly owned companies are not legally required to disclose many details regarding their financial and political activities, and private companies are obligated to disclose much less. As a result, this research likely represents an incomplete picture of the overall influence these companies have on the nation's climate science and policy discourse.

Inappropriate corporate influence on the national dialogue on climate science and policy is large-scale and complex, spanning multiple venues from the public spheres of government relations and media outlets to the more covert realms of think-tank funding and political contributions. In turn, the solutions for reducing this influence will also be large-scale and complex, requiring fundamental changes in how corporations and the federal government operate and interact. Transparency and accountability will need to be inherent to corporate-government relations, and the loopholes and mechanisms that allow corporations to inappropriately influence political processes will need to be eliminated.

Despite this complexity, we offer several recommendations for developing a more science-based dialogue on climate change in the United States. First, companies need to be held accountable to their statements and actions. This can be advanced through greater demands from consumers, investors, the media, and the public for transparency and accountability in the private sector. Shareholders of public corporations, in particular, are in position to effect greater change in such companies. Moreover, greater transparency in corporate political activities is needed. Policies that enforce disclosure of indirect corporate political contributions through outside groups, for example, can greatly increase corporate accountability. Lastly, these challenges also can be mitigated with greater oversight of corporate affairs from Congress and the Executive Branch, especially the SEC.

When the influences behind public policy making are concealed, the democratic processes of our government are vulnerable to corporate and political interference. To address corporate interference and ultimately mitigate the impacts of climate change itself, the United States needs greater transparency in governmental and corporate affairs. This will not only help illuminate how extensively companies are influencing the political process but also will help hold them accountable for their actions. Ultimately, we seek a dialogue around climate science and policy that prioritizes peer-reviewed scientific information over the agendas of special-interest groups.

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Chapter 2
Reaching Out Beyond the Usual Suspects and Traditional Media: Re-branding Climate Change as a Problem with a Feasible Solution

Geoffrey Haines-Stiles, Richard B. Alley, and Erna Akuginow

In her book on the slaughter in Rwanda and earlier mass atrocities, Power (2007) called genocide "A Problem From Hell". Dehgan (2013), Director of USAID's Office of Science & Technology, spoke of "wicked" global problems—meaning issues that are difficult, multi-dimensional, and seemingly impossible—including food supply, ecosystem loss …and climate change. In the United States, at least until recently, climate change has effectively been regarded as a kind of scientific problem from hell and definitely wicked. However, if our planet is not to warm and become a living hell for humans and the other creatures and plants with whom we share Earth, climate change cannot be left a wicked problem. Solutions adequate to the scale and complexity of the challenge must be found.

In the United States, however, climate change has become a political football, with "belief" or skepticism about its reality, pace, and causes strongly linked with party affiliation. All but one of the Republican candidates for the 2012 presidential nomination asserted that the science was not settled, despite the fact that approximately 97 % of all climate experts agree on the human role in changing Earth's atmosphere through the emission of carbon dioxide as a by-product of burning fossil fuels for power generation and transportation (Anderegg et al. 2010; Doran and Zimmerman 2009; also see Rosenberg et al. 2010; National Research Council 2011; Joint Academies 2005).

According to the Pew Center on the People and the Press (2011), the "Number of Americans who believe Earth is warming" declined from 79 % in 2006 to 59 % in 2010. Meanwhile, there was clear evidence that politics helped determine attitudes,

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as can be seen by surveys finding that 75 % of "Staunch Conservatives," 63 % of Libertarians, and 55 % of "Main Street" Republicans assert there is "NO solid evidence of global warming." On the other hand, 75 % of Democrats say that there "IS solid evidence of global warming" (Pew 2011).

Over these same years, the media landscape has been transformed, with rapid growth of social media such as Facebook and changing patterns of television use. Fewer people now watch programs at the time of initial broadcast, and more are opting for on-demand viewing made possible by the vast array of new technologies such as DVRs and online channels from YouTube to Hulu, Roku, and iTunes U (Melman 2012).

The "*Earth: The Operators' Manual*" initiative was an attempt to address the wicked problem of climate change in this partisan political environment and amidst this media revolution. The project combined public television programs and other media, and project design embodied findings from social science, geoscience, and economics. Long-time science TV producers Geoff Haines-Stiles and Erna Akuginow developed the project collaborating as partners in Passport to Knowledge, an independent science media developer and production company. They enlisted award-winning Penn State glaciologist and climate expert Richard Alley, a dynamic educator and communicator whom Andrew Revkin, writing in the *New York Times* (2009), once described as a "mix of Woody Allen and Carl Sagan," to serve as Science Editor, on-camera presenter and Co-Principal Investigator. A proposal was submitted to the U.S. National Science Foundation in December (Haines-Stiles et al. 2008), which issued an award letter in September 30, 2009. This chapter describes the project concept and goals, discusses the design; identifies what succeeded in terms of messages, messengers, and media; and concludes with lessons learned about communicating climate change and renewable energy solutions in a contested and rapidly changing media environment. We present both qualitative and quantitative data drawing from the project's external evaluation, which was executed by Rockman et al. (Sanford et al. 2013) (Fig. 2.1).

2.1 "Earth: The Operators' Manual" Concept and Goals

> A user guide… also commonly known as a manual, is a technical communication document intended to give assistance to people using a particular system… Most user guides contain both a written guide and the associated images… The language is written to *match up with the intended audience with jargon kept to a minimum or explained thoroughly*.
> (http://en.wikipedia.org/wiki/User_guide, emphasis added)

Contemporary society is energy intensive. With more than seven billion people on Earth—all of whom want, need, and deserve clean water and nutritious food, and most of whom also want to drive cars and use cell phones—it will become even more so. Fossil fuels—coal, oil, and natural gas—have brought industrial civilization this far, but the consequences of burning them can be seen in changes to the composition of Earth's atmosphere and in warming global temperatures. A sustainable future requires a transformation in the way we think about, develop, and use energy.

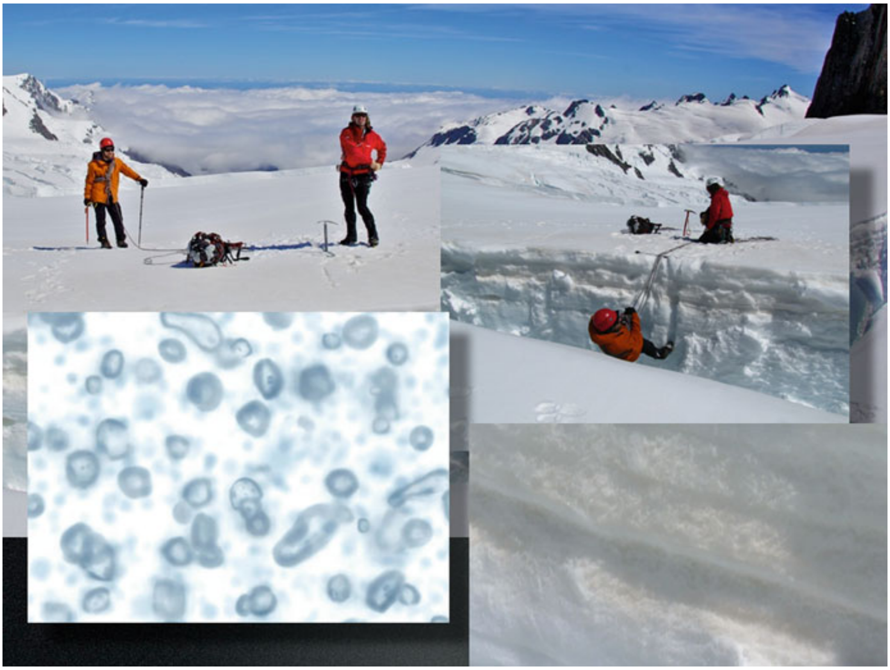

Fig. 2.1 Richard Alley (*orange parka*) about to descend into a crevasse to illustrate layering in snow and ice, which can be read—like tree rings—to sample Earth's ancient climate

"*EARTH: The Operators' Manual*" (ETOM) was proposed as a user guide to the present and future energy resources of our planet, designed both to prototype and rigorously evaluate new ways of providing "users"—meaning, all of us—with the *information*, *attitudes,* and *tools* needed to make wiser choices about powering our homes, schools, businesses, and communities. The project design was influenced by a close reading of social science studies of public health campaigns and what has come to be called *motivated reasoning*, where attitudes towards "facts" are based in part on demographics and group identification as much as on logic and pure reasoning (Kahan 2012, passim).

While research has long assumed that *knowledge* leads to *attitude change*, which is then followed by *behavior* change (emphases added), some researchers have found this KAB model inadequate. As Roser-Renouf and Nisbet (2008) argued,

> While information is generally a necessary condition for change, it is rarely a sufficient cause, and researchers on climate change are likely to focus on what types of information are needed to spur changes in behavior and build support for mitigation policies. (p. 44)

Instead, a review of current literature suggests *procedural knowledge*—knowing how to take action—has a stronger relationship to environmental behavior than does *declarative knowledge*—knowing, for example, that energy use produces damaging CO2 emissions (p. 45).

ETOM attempted to implement this approach to one of today's most important but often controversial topics. As Alley, Akuginow, and Haines-Stiles (2008) wrote,

> The twin energy problems—finding replacements for the finite fossil fuels, and doing so before the world is changed too much in bad ways—are arguably the biggest environmental problems we have ever faced, but they can be solved… Many thinkers believe it would be wise to invest now in the science and engineering that will lead toward solutions.

2.2 "Earth: The Operators' Manual" Project Design

> E-TOM is an innovative hybrid model of science communication that combines the power and reach of broadcast television and online video with the immediacy and impact of visually rich, in-person presentations at science centers and museums, extended further through the ongoing engagement and connectivity of Web 2.0 social networking. (Sanford et al. 2013, para. #)

ETOM embodies a multi-pronged approach to communicating climate change and sustainable energy via customized messages, credible messengers, and multiple media aimed at diverse broadcast, online, and on-site audiences. The project utilized four complementary media experiences to share information with the public, encourage audience members to engage in dialogue about climate change, and motivate audiences to take action to address issues of energy use. The project consisted of (a) television programs, (b) museum outreach events, (c) a website, and (d) social media initiatives. We report on each in turn, and show how, taken together, they helped rebrand climate change as a problem with feasible solutions.

2.2.1 Television Programming

ETOM developed 3 hour-long episodes to be broadcast nationally on the Public Broadcasting Service (PBS). Program One, *Earth: The Operators' Manual*, provided evidence of manmade climate change, outlined the problem of domestic and global energy demand, and examined several potential sustainable energy solutions. Program Two, *Powering the Planet*, focused on more in-depth examples of countries worldwide and communities here in North America that are implementing sustainable energy alternatives and outlined the challenges they face. Program Three, *Energy Quest USA*, looked at the environmental and economic concerns that drive energy choices in five different communities across the United States. Program One first aired in April 2011. Programs Two and Three premiered 1 year later, in April 2012 (along with a re-run of Program One). The initial airing of each program coincided with PBS's Earth Week programming in celebration of Earth Day.

2.2.2 Museum and Science Center Outreach

Five museum partners agreed to facilitate year-long ETOM outreach events at their institutions: the Science Museum of Minnesota (SMM), the Oregon Museum of Science and Industry (OMSI), the Fort Worth Museum of Science and History (FWMSH), the North Carolina Museum of Natural Sciences (NCMNS), and the Reuben H. Fleet Science Center in San Diego (Fleet). Museum events, which began in March 2011 and concluded in November 2012, took various forms, from program screenings and spoken word presentations by Richard Alley and other experts, to Science Cafés and outdoor festivals.

2.2.3 The Website

The ETOM website (http://earththeoperatorsmanual.com) initially launched in April 2011 in conjunction with the broadcast of Program One. It was then redesigned as part of the rebranding efforts (see The ETOM Website below), and re-launched in April 2012 to coincide with the re-run of Program One and the premieres of the two new programs. The website contains streaming video of the programs (each of which was also broken down into short chapters), information about PBS air dates, short web-exclusive video clips, widgets with interactive energy-saving tips for consumers, links to other ETOM resources and events, and more in-depth climate change and sustainable energy content.

2.2.4 Social Media

While Facebook may be dismissed by some traditionalists, ETOM has found it to be a dynamic, growing, and legitimate means of sharing the project's unique brand of climate science and renewable energy solutions. The project team first posted on Facebook March 5, 2011 (https://www.facebook.com/EarthTheOperatorsManual.Page), coinciding with the initial broadcast of Program One. Subsequently, the team reconceived the project's social media presence in April 2012. Since then, ETOM's Facebook page has been active and content-rich, featuring quotes from scientists and sustainable energy advocates overlaid on engaging images (both photographs and created graphics), tips for individuals to reduce personal energy consumption, examples of communities implementing sustainable energy initiatives and key facts about climate change (see Facebook and Social Media below).

2.3 Messages, Messengers, and Media That Worked

Rockman et al. (REA), external evaluators for the project, worked closely with the ETOM project team to devise strategies for examining the impact of each of the four media strategies and to examine the "additive contribution" of all four approaches working together. REA utilized qualitative and quantitative approaches to consider the degree to which each of the four ETOM media experiences addressed the following audience impacts:

- Learning new facts about climate change and/or sustainable energy (Information)
- Changing perspectives and interest regarding environmental issues (Attitudes)
- Increasing the likelihood of reducing individual energy consumption (Actions)
- Increasing the likelihood of discussing ETOM topics (Social sharing)

REA investigated the extent to which television program viewers, museum attendees, website visitors, and Facebook users experienced the above outcomes by collecting information from these audiences via surveys, interviews, focus groups, on-site observations, and online analytics. The anonymized audience quotations presented in this report were selected as representative of the overall findings.

2.4 Evaluating Television Programs: "Messenger" Credibility

Supported by focus group results, and consciously addressing the politicization of climate change, we chose to have Richard Alley introduce himself at the start of the first program with more personal background than normal in a science documentary. Writing about ETOM in the article, "Communicating Science in Politicized Environments," Lupia (2013) had this to say:

> What is critical here is that it is the audience's beliefs about a communicator that affect source credibility and hence, the communicator's ability to persuade. An audience must believe that they and the communicator have common interests and, with respect to the topic at hand, the audience must believe that the communicator knows things that they do not. If the audience perceives the communicator as lacking either quality, the communicator will not be credible regardless of how many PhDs or publications they have… These findings imply that science communicators can establish source credibility by taking the time to relate their own interest in a scientific problem to a core concern of their audience… An example of this strategy is found in the opening minutes of the PBS television program called *Earth: The Operators' Manual* … In it, Alley reveals himself to have valuable expertise on the topic as well as common interests with typically skeptical groups (Lupia 2013).
>
> (Richard Alley, voice over) *I'm a registered Republican, play soccer on Saturday, and go to church on Sundays. I'm a parent and a professor. I worry about jobs for my students and my daughter's future. I've been a proud member of the U.N. Panel on Climate Change and I know the risks. I've worked for an oil company, and know how much we all need energy. And the best science shows we'll be better off if we address the twin stories of climate change and energy. And that the sooner we move forward, the better.*

Fig. 2.2 Some of the diverse faces of those appearing in ETOM (*clockwise from top left*): musher and renewable energy expert, Gwen Holdmann; rancher Steve Oatman; Senator Lisa Murkowski (R, Alaska); Baltimore Energy Captain Robynn Lewis; B/G Bob Hedelund, Marine Corps Warfighting Lab

Lupia (2013) continues "[A]ctions such as Alley's, which establish common interests and expertise, should not be considered peripheral aspects of the presentation. In many cases, these actions will be necessary to get an audience to learn the intended lessons. *To persuade an audience to think about science in politicized environments, high credibility is a must*." (Emphasis added)

In addition to Alley, who hosted all three programs, a diverse cast of on-camera experts helped tell the story, including then Oceanographer and Navigator of the U.S. Navy, Rear Admiral David Titley, commenting on the Pentagon's acceptance of the reality of climate change, as stated in the 2010 Quadrennial Defense Review (U.S. Department of Defense 2010). Texas rancher Steve Oatman, describing himself as unsure about the causes of climate change, nevertheless joined Houston Mayor Annise Parker in endorsing the contribution of wind energy to the nation. Republican Senator Lisa Murkowski listed Alaska's sustainable energy resources and Baltimore Mayor Stephanie Rawlings-Blake, a Democrat, endorsed the volunteer efforts of the Neighborhood Energy Challenge in cutting both energy costs and polluting emissions. ETOM wanted the suite of video elements to "look like America," reaching out beyond committed green activists (Fig. 2.2).

On April 21, the New York Time's environment reporter, Justin Gillis wrote that ETOM is:

> . . . one of the more interesting documentary series to come along in years… The basic idea is to lay out the problem of climate change in the first episode and then talk about how to fix it in the others… [Richard Alley] and the producers manage to call forth a surprising

> diversity of voices in support of taking action to both conserve energy and convert to renewable energy sources. These include farmers, poor people, Republican lawmakers, military brass, and native Alaskan villagers. Senator Lisa Murkowski, the Alaska Republican, says in one episode, "What is more conservative than harnessing what is available around us in a long-term, sustainable way?" (Gillis 2012)

As Alley stated in his Invited talk at AGU 2012, "Voices do matter! Some people who would ignore me will listen closely to Rear Admiral David Titley or rancher Steve Oatman. *WE reach more people than I do!*" (Alley et al. 2012) (emphasis added).

Reactions, reported by Rockman, support this approach. Viewers wrote, "I was thinking about my parents—being conservative, former military…" and "…the combination of the science and a rural town and the profitability made it interesting…".

In another *New York Times* article, media columnist Brian Stelter (2012) wrote:

> . . . producer, Geoffrey Haines-Stiles, said they had found their own way to address the science behind climate change: by pairing climate change talk with discussions about energy conservation and new technologies. "Our approach is that folks will take climate change more seriously if they also see what can be done—practically, personally and immediately—to address it," he said.

2.4.1 Compelling Stories, Capable Storytellers

The IPCC and the U.S. National Climate Assessment may properly communicate in reports thick with charts, acronyms, specialized terminology, and footnotes, but effective engagement with the public requires stories, metaphors, analogies, and compelling storytellers. We enlisted Richard Alley for his unique combination of impeccable scientific credentials (including service on the Nobel Prize-winning IPCC) and literary and live performance skills—along with a certain amount of physical courage. For example, during filming for ETOM, we took him down into a deep crevasse in New Zealand, and over a bungy jump to help illustrate abrupt climate change. Both broadcast audiences and crowds at the live events responded favorably to Richard and this approach (Fig. 2.3).

Nielsen ratings showed that the first and second programs reached a cumulative audience of some 3.6 million viewers, roughly twice that of a typical Fox News broadcast, and almost four times that of a primetime MSNBC program (TV Newser 2013). Carriage reports showed that *Powering the Planet* and *Energy Quest USA* were carried by stations that reached more than 80 % of U.S. households over the air, and all three programs were also distributed as part of the *PBS World* digital service, providing multiple opportunities for time-shifted viewing in close to 40 major US TV markets.

2.5 Audience Reactions

Viewer comments on ETOM's Facebook page after the Earth Day broadcasts replaced the traditional letters-to–the-editor. Excerpts are shown below with slight grammatical corrections and initials for confidentiality.

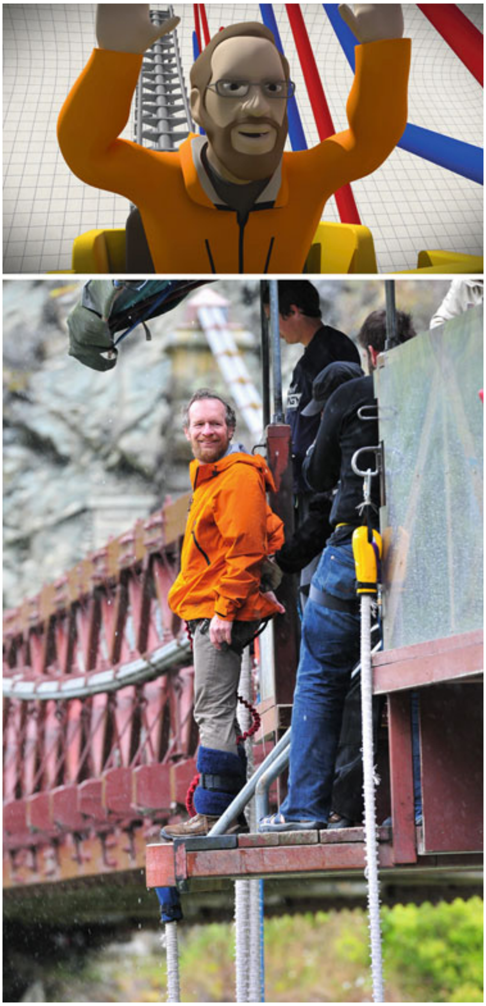

Fig. 2.3 A computer graphic avatar of Richard Alley rides the "climate roller coaster," and Alley about to bungy jump at the Kawarau Gorge bridge, New Zealand

…all of this information can be so conflicting, confusing & disheartening, and it's nice to have something constructive to latch on to, to help us feel as if there's something we can do to help while we watch politicians fiddle faddle bark & waddle our planet away …thanks, EARTH! (BB)

Friends, if like me you breathe air, turn on a light switch, drive a car, and flip on the furnace or A/C …this program is a must. It also helps if you care about your Earth and your posterity. You'll love this and want to be a player in helping effect changes in your lives. (RE)

…It is really cool to see a show on climate change which is actually showing how the world is reacting in a positive way, coming together and making changes, rather then just showing all the negatives. Scenes of drowning polar bears only depress people and make them watch American Idol. But ETOM maintains a "can do" attitude when it comes to telling the viewer that things can be turned around. (NH)

Table 2.1 ETOM television program outcomes

Outcome	Strongly disagree (1)	Disagree (2)	Agree (3)	Strongly agree (4)	Number of respondents	Mean
Increased my interest in this topic	0	1	23	21	45	3.44
Gave me new information about climate change	0	1	27	17	45	3.36
Gave me new information about sustainable energy	0	4	20	21	45	3.38
Changed my perspective on environmental issues	2	19	17	6	44	2.61
Encouraged me to take action	0	7	28	10	45	3.07
Makes me want to seek out further resources or information	0	3	26	15	44	3.27
Encouraged me to have discussions about this topic with others	0	7	21	17	45	3.22

Rockman recruited viewers throughout the duration of the ETOM project to provide feedback on the three television programs via surveys. Some 1,045 adult respondents completed a survey, answering at least one question about the programs. ETOM viewers were most likely to “Agree” (3) or “Strongly agree” (4) that the programs increased their topic interest and provided them with new information about climate change or sustainable energy. In fact, 82 % of viewers (N = 55) indicated that they had learned new information about climate change or sustainable energy alternatives from the programs (Table 2.1). Three themes stood out in terms of grabbing viewers’ attention and providing valuable information: (a) evidence for human influence on Earth’s changing climate, (b) ways in which alternative energy solutions are used in different countries and in the United States; and (c) military perspectives on climate change and alternative energies.

ETOM’s overall tone of the program was seen as optimistic: “This one leaves you feeling positive about things that can be done, when usually it is doom and gloom.” (Viewer post on the ETOM FB page) 93 % of viewers (N = 45) also felt that the program presented information in a way they had not previously seen on television, offering *a different perspective*. They appreciated the detailed explanations of climate change concepts and the viable solutions to the energy shortage problem as illustrated by one response,

> Instead of giving generalizations and, “Yes, there is global warming,” this gives you the facts… Then it moves on to the next element of the program and it explains it and it gives the evidence, and it backs up what it is saying.

Viewers liked that the programs presented unexpected perspectives, such as Richard identifying himself as a Republican upfront and showing what the military is doing with sustainable resources. "When the military is showing that it is pragmatic to be green and they are in the field using it, not just hippies with solar panels on their roofs, it lends a lot of credence," wrote one respondent.

2.6 Evaluating Museum Outreach

> We've all heard a ton about [the topic], so you're a little bit leery going in that you're going to get bored to death or hear the same things that you've heard time and time again, but [the speaker] was really good… I thought he was really clear and articulate in his descriptions and it was super easy to follow.

ETOM events at its museum and science center partners began in Spring 2011 and continued through Fall 2012. Each event involved extensive discussions between the museum partners and ETOM staff and principals, with story content, graphics, and video clips customized by the specific presenters (i.e. Richard or others) and tailored to address local interests. Events ranged from presentations by Alley in San Diego, Minneapolis, Portland, Raleigh and Fort Worth; to "Military Goes Green" events with active duty Marines, Navy captains, and retired Army Colonels at NCMNS and Fleet; and Science Café's with *DotEarth* blogger Andy Revkin, and venture capitalist and "clean coal" proponent Albert Lin. Each 2 to 3-day visit involved multiple venues, including universities and small group presentations to museum staff and trustees. Events in Portland, detailed below, typify the approach and results.

On Wednesday November 7, 2011 at one of OMSI's ongoing series of Science Pubs at Portland's Bagdad (sic) Theater, Alley delivered a presentation similar to one he had recently given at SMM, modified in light of audience feedback from the earlier event. In surveys and interviews, respondents in the Twin Cities/SMM said they wanted, for example, to hear more about how to respond to skeptics. In response, ETOM added "But My Brother-in-Law says…" rebuttals to a series of commonly heard arguments about the influence of the Sun, the role of volcanoes in climate change, whether the Earth stopped warming in 1998, and the idea that its climate is always changing, all illustrated with graphics and personal comments. The OMSI presentation was also customized to feature local officials and community members interviewed for the third ETOM TV special, including Portland Mayor Sam Adams and Egbevado Ananouko from the city's "We All Can Ride" project (Fig. 2.4).

A large audience almost filled the venue, and the informality of the location, with food and drinks available, resulted in a lively and informative question and answer period. (The illustration above adds Alley's name to the marquee via photo editing, emphasizing the theatrical feel of the event.) 28 % of attendees indicated that they had not thought a lot about climate change prior to the event—a surprisingly high percentage for "green Portland." Yet regardless of whether they had thought about climate change before or not, 93 % of attendees felt that they had learned something

Fig. 2.4 This figure adds Richard's name to the marquee via photo editing, emphasizing the theatrical feel of this successful event

new about climate change. And while 21 % indicated that they had not thought about sustainable energy alternatives before—another surprising statistic—a total of 77 % also said that they had learned something new about this topic.

> What I found most useful about this program is that it brought the science to a much more manageable level, so you could have a good cocktail conversation with this information because he's giving you metaphors for it and breaking it down in ways you can remember like, "How many parts per million?" and I remember it's 280 because he did a really cool graph with the roller coaster, so I think it brings it into the public discourse if you're able to understand these issues in a conversational level.

The event also included a screening of a rough-cut sequence (intended for Program 2) comparing the projected cost of transitioning to a low-carbon energy system with the historical investment in indoor plumbing made by cities and nations in previous centuries to replace chamber pots and the practice of dumping human waste out of windows. This segment, shot on location in Edinburgh, Scotland, and based on a story that appealed to both Alley and Haines-Stiles (Repcheck 2003, pp. 52–54; Alley, 2011, pp. 211–214), was called "Toilets and the SMART GRID."

> I thought the comparison to plumbing was amazing. I hadn't heard that before. But it was a really good connection when people say, 'We don't have the money, we don't have the resources, we don't have the energy to make this sort of major shift.' I thought it was a really amazing point.

Ninety-four percent of survey respondents agreed or strongly agreed that the event presented information in a way they had not seen before. In interviews, attendees indicated that they liked Richard's ability to present information in layman's terms:

> Knowing an answer is one thing, but being able to tell the story so that people can understand it is a real gift and he does that well.

The Science Pub appeared most successful in increasing attendees' interest in the topic (95 %), encouraging them to discuss these topics with friends (92 %), and making them want to seek out information on their own (89 %).

ETOM's on-site components were a rich and varied set of outreach experiences involving different styles of presentations, content customized to local interests and venues, but all directly related to the underlying content of the project. Scientists and non-professional attendees alike appreciated that the museum outreach events:

> *…gave us language that we can use to communicate to other people, and* I think that's what we need more than more data. *We need to know how to frame the arguments. We need to know how to talk to people. How to address it, and I think that's what [the speaker] did.* (emphasis added)

2.7 Evaluating Online Communication

ETOM's online components included:

- The main project website, (http://earththeoperatorsmanual.com) which was completely redesigned and re-launched in 2012, to support the PBS Earth Day specials
- The "Energy Gauge", as described in the original project proposal
- Social media pages on Facebook and Twitter, with a primary focus on Facebook

Each of these elements will be discussed in turn.

2.8 The ETOM Website

The original proposal focused primarily on building an informational website with blog material contributed by Richard Alley and others, together with an "Energy Gauge" adapted from one created by a small Boston start-up. PBS broadcasts were to be the primary outlet for distributing video content, with minimal video posted online due to concerns about copyright infringement and piracy of the broadcasts. Every aspect of this approach changed radically over the lifetime of the project.

While the ETOM website which debuted in 2011 was generally very well-received, Rockman's focus groups and online surveys indicated possible improvements in design, functionality and approach. In addition, the ETOM staff responded to the rapidly evolving online universe, and to feedback made at the various presentations in which ETOM was featured. At the NSF-supported "Carbon Smarts" workshop on informal climate science outreach, Haines-Stiles heard an interesting presentation by Rob Gould of Brodeur Partners. Gould (2007) had been a principal involved in the design and execution of the "Truth" campaign, funded by the Attorneys General settlement with the tobacco industry (e.g. Farrelly et al. 2002; also see http://www.thetruth.com/). That campaign's success in tackling another "wicked" problem, underage smoking, and its lessons learned about applying Madison Avenue tactics to social issues, seemed directly relevant to ETOM as we read the results of public opinion surveys in 2011 and late 2012, most of which showed a continued decline in Americans "belief" in climate change and diminishing support for the implementation of renewable energy solutions as indicated in the chapter introduction. ETOM therefore retained Brodeur Partners as consultants to help rebrand the project. Our objectives were to:

- *Increase Reach*—to expand beyond the PBS audience who would naturally have the greatest "organic" access to our content.
- *Increase Share-ability*—to give tools to the "converted" to help spread the word. We wanted to empower the widest possible audience to take action in their own lives, and in their communities.
- *Extend Lifecycle*—to extend our video content and resources beyond the 2012 PBS broadcasts into a format that would outlast the airings themselves.

Based on those goals, we identified our primary audiences as follows:

- *Watchers*—Regular PBS viewers, scientists and activists, with a high representation of "alarmed" and "concerned" citizens, as described in the series of "Six Americas" surveys. (Leiserowitz et al. 2010–2012)
- *The Middle*—The "middle" Six America audiences who stood to be particularly informed and empowered by ETOM content.
- Relevant *Niche Audiences*—Specialist audiences featured in core ETOM content, such as the military, rural America, religious communities, and moderate Republicans.

The website was redesigned with the following major components (Fig. 2.5):

Join the Conversation / Energize Your Community /
Don't Wait, Do Something Now / Watch and Share

The new site would still, of course, provide more straightforward and necessary information, such as when local PBS stations would be carrying the programs. But also, and increasingly importantly given the shift from TV sets to computers and mobile devices, we chose to share all programs and program segments online, hosted on YouTube for ease of access and embedding by third parties. Educators would continue to be able to register for free and download segments for in-class use. In addition, each program would have its own fully annotated script, citing sources for all facts and statements used in the narration. Furthermore, the site's "Watch and Share" section was broadened to include a series of web-exclusive features, from science content repackaged as "How To Talk To An Ostrich" (suggested by responses to Richard Alley's live presentation in St. Paul) to "Communities Taking Control" to "Meet The People Who Are Energizing America" ("Energy Heroes" for short). As done for the independent features *Food Inc.* and *Waiting For Superman*, ETOM also encouraged local Watch Parties, enabling individuals and groups (like church congregations and university dorms) to register and freely

Fig. 2.5 Layout of the redesigned website as of April 2012

download HD versions of the programs, stored behind a password on Vimeo. Local screenings and Watch Parties have since been organized in locations as diverse as UC Chico CA, Reston VA, across Kansas and in many other locations in October 2012, in connection with Richard Alley's presentations to *Pennsylvania Interfaith Power and Light*.

When REA asked respondents to select from possible answers to complete the prompt, "This website…":

- 100 % answered it "is inspiring",
- 88 % answered it "increased my interest in this topic",
- 88 % answered it "presented this information in a way I hadn't seen before",
- 76 % answered it "gave me new information about sustainable energy",
- 71 % answered it "gave me new information about climate change", and
- 35 % answered it "changed my perspective on environmental issues".

Most significantly in terms of energizing primary audiences to share the information with others, when REA prompted, "Now that you have been to the website, how likely are you to do the following…?":

- 98 % said "Have discussions about this topic with others in person or online",
- 93 % said "Seek out further information or resources on the topic",
- 93 % said "Take personal action to reduce my energy consumption", and
- 81 % said "Get involved w/ environmental initiatives in community at natl. level".

2.9 The Energy Gauge

As seen in responses to the live events, and in online surveys, viewers and visitors to the website very much wanted information about how to *do* something about climate change, not just to absorb factual information. Our original online developer, as well as many other "energy gauge" publishers, including Microsoft and Google, folded their offerings; however, we believed that it was worth making every effort to fulfill the promised Energy Gauge deliverable described in our 2008 proposal, despite the considerable challenges. Accordingly, ETOM contracted with *Ennovationz*, a software developer that had acquired the database and underlying algorithms of MacArthur "Genius" Saul Griffith's existing energy tool, and adopted the existing WattzOn name and logo. For close to a year, ETOM and the new WattzOn collaborated intensively on the design and content of an exciting new Energy Gauge, which was later seamlessly integrated into the "Don't Wait, Do Something Now" section of the re-launched website.

The Gauge includes a set of five widgets, with freely available APIs so that any site may install them, all displaying the ETOM logo and with an embedded link to our website:

- **Rebates** provides a list of all government and private energy-saving incentives, by zip code
- **How I Compare** allows users to see how their utility bill compares to their neighbors
- **Diet and Energy** shows how much energy is consumed to create the food we eat
- **Solar Home** shows how much money a household can save by installing solar panels
- **Hybrid Car** enables users to compare the energy efficiency of any make and model of automobile with any other car, including the latest hybrids

For those willing to spend more time entering household data, the WattzOn site also enables a detailed comparison of how much energy is used by specific appliances or functions (e.g., lighting or heating) and provides a handy set of tips and suggestions to serve as a ready-made action plan, displaying changes in energy use either in terms of dollars saved or BTUs and kilowatt hours conserved.

ETOM wanted to go even further in allowing users to see the potential results of making changes in other areas of a typical lifestyle. Therefore, collaborating again with WattzOn, we came up with **WattIS/WattIF** calculators for Diet, Driving and Flying. Users can enter data on their current behavior in these categories and immediately calculate their impact on the environment, in terms of energy used or CO2 emitted. The **WattIF** tool allows users to evaluate changes to their energy consumption, such as the decision to drive or fly less, buy a hybrid automobile or eat *less* beef and *more* chicken and vegetables, and then see the potential differences quantified and graphically displayed in energy savings or emissions avoided. Each set of changes can be saved as a new **WattIF** scenario, allowing users to experiment with energy lifestyle choices in an easy, immediate way that is relatively unique in terms of online tools (Fig. 2.6).

Fig. 2.6 How cutting back on beef and eating more grains impacts energy use

Following the re-launch of the site, evaluation results showed some notable differences between the impacts of the improved and the original site.

- The redesigned website was significantly *more effective* in providing users with new information about climate change.
- The redesigned website was also significantly *better* at providing users with new information about sustainable energy solutions.
- Users of the redesigned website felt significantly *more encouraged* to take actions to reduce their energy consumption than those who used the older version of the website.

2.10 Facebook and Social Media

ETOM initially launched its Facebook page on March 9, 2011. A new version of the page debuted in conjunction with the premieres of the two new ETOM programs and the project's website re-launch on April 16, 2012. Throughout the life of this project, Facebook frequently changed its page layout (implementing the "Timeline" display), features, statistical tools (called "Insights"), underlying algorithms and more, necessitating continuous care and feeding of the page. In Spring 2012, ETOM applied the same rebranding and approach described above for the website to

Fig. 2.7 Examples of popular ETOM Facebook posts

Facebook and hired its current new media coordinator. Our plan is to continue experimenting with what most successfully attracts "Likes" (requiring only a simple click), and what best motivates "Comments" and "Shares" (somewhat more time-consuming activities) but which provide what social media experts term "Engagement," a deeper interaction with content. In terms of "Likes" some of the most popular postings have been dramatic images with brief key quotes and links, with memorable statistics about positive examples, from the United States and around the globe, about practical energy-saving advances. At the same time, posts on record-low Arctic sea ice extent (ETOM FB Sea Ice 2012), or Richard Muller and the Berkeley group's re-analysis of surface temperature data (ETOM FB BEST 2012) have also attracted large numbers of Likes and Shares, showing that the ETOM Facebook community is interested in and engaged with both climate change science and renewable energy solutions (Fig. 2.7).

While any one set of Facebook statistics is at best a snapshot in time, and Facebook often changes its algorithms in ways that are obscure even to page Administrators (and downright confusing to users), ETOM's Page had grown by February 2013 to more than 28,500 Likes, with "Friends of Fans" amounting to some 13,600,000. More meaningful, however, is what might be termed the "Engagement Index", calculated as the ratio of those exposed to a post who "Like" that post and either "Comment"

Fig. 2.8 ETOM's Facebook "Insights" for February 20th, 2013

and/or "Share" it with their own Friends, compared to the number of total Likes. By this criterion, in a bundle of ten environmentally-oriented Facebook pages, ETOM ranks below NRDC (the Natural Resources Defense Council) and the hip and hugely popular "Science is Awesome," but above such long established groups as the Sierra Club, Greenpeace International, EarthSky and even the main PBS page (Fig. 2.8).

While Facebook Insights gives a cyber-age twist to the old saying about "R, damned Lies, and Statistics," it does seem that our social media strategy is engaging a substantial online audience. According to Brodeur Partners, ETOM is "punching above its weight" in the battle for engagement (personal communication, February 19, 2013). Using the indisputably objective criterion of Facebook's "Talking About" statistic, ETOM ranks above WGBH's long-running NOVA series (whose page launched in 2008 and which has approximately 5 times the numbers of raw "Likes" as ETOM). Similarly, National Geographic's excellent "Project NOAH" page has approximately 15 times the number of ETOM "Likes", but there are substantially fewer people "Talking About" its page. Demographic data also shows that the ETOM Facebook community trends much younger than PBS viewers or visitors to the website, and that within this important demographic it tilts more toward "younger female" than toward "younger male." As we move ahead to support the project's online resources through the end of the PBS license period (as late as Spring 2015), we have substantial evidence to support the claim that ETOM's brand of solid science and positive solutions has found an enthusiastic and growing audience.

In an online Focus Group of those responding to an online solicitation, Rockman analyzed page data and captured such comments as: "It is solidly solution-oriented. Here are the data. This is the problem. (Here) are some of the most effective solutions …The objectivity is a nice change from much of the fact-lite whininess [on other sites]." Another commenter said, "Great graphics, great videos, original

Fig. 2.9 Still image from the generic title sequence for all "How To Talk To An Ostrich" online videos

stories that haven't been over-exposed online already." In terms of specific posts, one user highlighted the "How To Talk To An Ostrich" series of web-exclusive videos as "hands-down the most effective climate communication clips out there." Another user linked to ETOM videos on his own "Climate Bites" channel and said the following about the same series, "[It] is amazing. The best climate videos to date—by anybody. You somehow manage to use the Ostrich metaphor without being too insulting. Love the May 16 photo of an ostrich's mouth wide open!" (Fig. 2.9).

Some users appreciated the variety of viewpoints presented on the page:

> I was (pleasantly) surprised that it goes beyond science education into policy, psychology, behavior change… (i.e. it is far broader and goes far beyond the original ETOM PBS show. That was a surprise.)

Others noted that ETOM has a similar perspective to other climate change efforts, but the difference is that the information is credible and solutions-focused:

> …ETOM has stayed above the dirty by citing DATA.
>
> The main thing is to keep ferreting out material that has not already been over-exposed on Grist, Climate Progress, Climate Central, etc. A place to find stuff that doesn't appear elsewhere.

The Facebook focus group also demonstrated how some Page members planned to use ETOM resources:

> I reference the links all the time in online discussion with my friends …They then react to the posts.
>
> I've been sharing the content on the ETOM Facebook page with friends and in other forums…Whole Foods, Haven's Kitchen in NYC…

When the ETOM project began in 2008/2009 we could not have anticipated that our mission would evolve beyond sharing Richard's stories via broadcast television and in-person presentations to curating an online treasure-house of short stories, links and graphics—and, in turn, empowering third parties to populate their own social media pages with fresh content. Another unanticipated but welcome development is that it is often third parties, completely unaffiliated with the ETOM project (i.e. not staff employed and paid by us) who seize the opportunity to rebut misinformation posted by aggressive climate skeptics and "internet trolls." While our social media coordinator rapidly removes abuse, we do encourage lively, informed debate, and the pointed and often humorous corrections of fact by interested and knowledgeable third parties are, we feel, a legitimate component of the ongoing ETOM mission and vision.

2.10.1 Website vs. Facebook

As noted above, the initial proposal had anticipated relying primarily on the project website for the most substantive content and interaction. However as social media channels developed, most participants in REA's surveys preferred the ETOM Facebook page to the website. They reported that they liked Facebook because it is easily accessible when they log on for personal reasons (as close to one billion now do, often many times each day), convenient, serves as a "central source for interests," is a convenient way to seek and access news content, and is designed for browsing on mobile devices. In addition, users appreciated that the information presented on the page was clearly explained and always up-to-date. (As one commentator said, "*The most important thing about the Information Age is not to let your information age*.") In fact, several people found the ETOM Facebook page to be the best way "*to stay on top of environmental issues*."

As with feedback on the PBS broadcasts and on-site events, responses from many Facebook page users indicated that they had used or planned to use information from ETOM's page during online or in-person discussions with friends or family members, particularly those skeptical of manmade climate change. Other respondents said they had reposted ETOM resources on other environmentally focused websites. Additionally, some educators who became members of our social media community incorporated ETOM resources and concepts into their high school and college courses. Teachers also reported sharing ETOM resources professionally. One educator mentioned, "*I often share ETOM posts on my Educational FB pages for teachers*." Individuals also mentioned reposting ETOM resources on other environmentally-focused websites.

2.11 Lessons Learned

Alley summarized his own personal and professional "Lessons Learned" in an Invited talk at AGU 2012: *"Better communications on climate and energy are needed for a better and more-sustainable world. And we communicate better if we:*

- *Use a wide range of media*
- *Use a wide range of voices*
- *Tell compelling stories honestly*
- *Share hope as well as danger*
- *Empower other communicators."*

A candid assessment of the relative success of the four outreach strategies—TV broadcasts, presentations at museums, website and social media—suggests that the least efficient was science center outreach, simply in terms of *number* of contacts. Each event/site attracted hundreds of attendees as opposed to the many tens of thousands interacting with ETOM content online, and the millions watching the TV programs. On the other hand, museum audiences served as large and highly valuable focus groups, whose reactions to rough cuts of sequences such as "Toilets and the SMART GRID" and "Look Before You Leap" influenced the final editing of the broadcast segments. Though harder to quantify, observations of audiences reacting in real time to Richard's stories and listening to comments during extended Q&A sessions did influence the evolving content and approach of the overall project. Furthermore, we believe that the live ETOM events were less about "preaching to the choir" and more a case, in Alley's words, of "*empowering the choir with good communication strategies and stories. We can't talk to everyone, but we can talk to people who do*." Evaluation data shows that audiences left ETOM events with new ways to share science-based arguments with friends, relatives and even skeptics, using fresh and compelling metaphors and analogies. As Rockman reported, "*ETOM's initial reach was expanded by its base of interested and galvanized individuals to reach out to others who did not yet hold the same beliefs*."

In the chapter introduction, we noted that ETOM was first proposed at a time when the clear trend was that that fewer and fewer Americans believed in human-caused global warming and the need for clean energy solutions. Since 2009, the Solyndra bankruptcy was often cited as evidence of problems with government financing of clean energy solutions. Many analysts also cited the financial crisis and high levels of unemployment with under-cutting broader concerns about the environment, with jobs becoming issue number one. However, by 2012, there was a noticeable change in public opinion. An update of the continuing "Six Americas" study found the following results, with considerable change even during 2012 itself. In response to the question, "Do you think global warming is happening?" in 2010, 57 % responded positively. By 2012, this had grown to 70 %, an increase of 13 points. And even from March 2012 to September 2012, there was an increase of 11 % in positive responses to the question, "Is global warming a growing threat to people in the United States?", rising from 46 to 57 %.

What happened? Record heat, record floods, and wild fires in Texas and across the Western states impressed upon Americans the fact that conditions are changing in significant ways. Climate scientists pointed out that whether any single weather event could be attributed to climate change, these extremes were all consistent with predictions of what will happen in a warming world. SuperStorm Sandy in late October 2012 only reinforced this shift in public attitude, with the scenes of destruction on the Jersey Shore, Long Island and New England. The increase of eight inches of sea level rise between 1950 and 2009 on America's Northeast coast clearly added to the high tide and storm surge to flood a large section of New York City, blacking out homes and businesses for long, cold weeks (Sallenger et al. 2012). Climate change was no longer a wicked problem to be talked about in terms of future impacts in distant lands. It had come calling in the home of major television networks and other media, literally arriving on sodden doorsteps.

Real world events have begun to impact public opinion, opening a door for an ongoing contribution by the science-based, solutions-oriented approach we offered in ETOM. Evaluation data documents the value of re-branding climate change as a problem not "from hell" and beyond human control, and not irremediably "wicked," but amenable to feasible approaches. If Texas ranchers and mayors, and Republican Senators (Lisa Murkowski in Alaska) and Democratic Congressmen (Earl Blumenauer in Portland), utility executives and community activists in Baltimore, and bankers and students in Kansas can be seen to agree that clean energy solutions lead to jobs, more secure energy supplies and less pollution, then there is a way forward. If that message can be taken up in YouTube videos, in the continuing use of media in classrooms and church groups, then a 3-year project can have enduring impact with a "long tail" (Anderson 2008). In comments from such strange bedfellows as the mainstream *New York Times* and guerilla videos from "Climate Crock of the Week", ETOM is regarded as innovative, interesting and effective, contributing new ways of communicating the climate science and renewable energy information that is so important to the health of our nation and the planet.

> I feel this needs to be seen by everyone. The way information is presented is not like anything I have seen before. It's very, "Here are the facts. We can either change our ways, or not. But the Earth will go on with or without us."

In general, participants felt that ETOM presented credible experts, compelling visuals and easy-to-understand fact-based information, and that its four media types were all "*solidly solutions-focused.*" In the words of one Facebook user, ETOM is, "*More cheery and optimistic than most stuff on climate, which reflects Richard Alley's style. Sort of a 'we can do this' approach rather than doom and gloom.*"

GHS thinks it should and that is how it was in the Drake version we saw last.

In summary, ETOM media met key project objectives:

- Participants who engaged with ETOM resources learned new information about climate change and sustainable energy and became more interested in those topics, even if they already had strong beliefs about human-caused climate change.
- They also felt more encouraged to take action to reduce their own energy consumption, and wanted to seek out new resources for their own intellectual benefit and for use in conversation.

Finally, as noted in Rockman's Summative report, one of ETOM's most important contributions is in providing a successful example of an integrated approach to science communication. Audiences encountered ETOM in multiple ways—through television programming, museum outreach events, a well-populated website, and various social media—and numerous participants experienced ETOM through multiple methods. The television programs concentrated on information dissemination and learning goals, while the online elements mainly targeted activities and mechanisms to encourage individual action on clean energy solutions and the sharing of useful information with others. The core strength of the project turned out to be its cumulative impact on participants' knowledge, attitudes and behaviors, which likely could only have been achieved by incorporating multiple media.

Climate change may still be "wicked"—difficult, complex, challenging long-held assumptions, requiring many of us to leave our comfort zones, necessitating international collaboration on an unprecedented scale—but by showing that there are feasible solutions and by making pragmatic resources available and easily sharable, ETOM shows that this is not an intractable "problem from Hell." Today's climate change is caused in large part by humans, and humans—working together—can solve it.

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Chapter 3
Investigating Connections Between Industry Affiliation and Climate Change Attitudes

Sue Schrader, Chris Danielson, and Scyller J. Borglum

"What do you do?"

Among adults meeting for the first time this question commonly surfaces in conversations, including during discussions about climate change. But when the topic is climate change, voices coming from the oil and gas industry send mixed messages. In 1997, Heinz Rothermund, managing director at Shell, UK, stated:

> How far it is sensible to explore for and develop new hydrocarbon reserves, given that the atmosphere may not be able to cope with the greenhouse gases that will emanate from the utilization of the hydrocarbon reserves discovered already? Undoubtedly there is a dilemma. (As cited in Greenpeace 1998, p. 7)

In the same year *Offshore Journal* reported: "1998 will see record spending by oil companies and continued expansion of the oil industry into new frontiers" (as cited in Greenpeace 1998, p. 17). In 2009, *The Guardian* reported that Exxon Mobil was continuing to fund climate skeptic groups despite making a pledge to cut such support (Adam 2009), and a second *Guardian* article cited papers that a well-known climate change skeptic, Willie Soon, received significant funding from major U.S. oil companies (Vidal 2011). Soon promotes the view that global warming is caused by solar variation, a notion disputed by a number of independent researchers. As noted by Lockwood (2008), over the last 35 years the sun and climate have been moving in opposite directions, and analysis shows the sun has had a slight cooling effect in recent years.

Responses like those above to the issue of climate change come from industry leaders and well-known scientists funded by industry to conduct research in this area. Significant work has been done in books such as *Manufacturing Doubt* (Oreskes and Conway 2010) to shed further light on how scientists typically funded

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by industry attempt to sway the population on issues including climate change. The goal of this work, however, is to move away from the leaders and spokespeople and look at the perceptions of climate change among the *rank and file* of the oil and gas industry and compare it to a control group of people in other industries with similar education levels.

3.1 Research Uncovers Variables That Correlate to Climate Change Views

Many studies have been conducted to measure the public perception about climate change. Some have focused on the general public perception over time, while others have highlighted the age of the respondent or the political party. The level of education of the respondents has also been correlated with their perceptions of climate change.

Surveys conducted by Gallup and collected by Pidgeon and Fischhoff (2011) show that while the number of Americans who believe that climate change is occurring is above 50 %, it has declined to 52 % recently down from a high of 65 %. A similar slight downward trend was noted in Great Britain, although a much higher rate of people believed that climate change is occurring (Gallop Organization 2007). Some have speculated that this is due to climate change being a lower priority issue that falls when concern about other issues such as terrorism or the economy rises (Upham et al. 2009).

Feldman et al. (2010) conducted a survey focusing on the perceptions of climate change of those under 35. The results were somewhat surprising, while those in that generation grew up with the discussion of climate change, their response to the issue was not predictable and surprisingly, they tended to be slightly less likely than the older generation to believe climate change is human caused.

However, according to the data collected by Semenza et al. (2008), those people who had graduated college were more likely to be concerned enough about climate change to modify their behavior than those without a college education.

With this current work, and its focus on comparing oil and gas industry employees to similarly educated employees in other industries, it is helpful to understand the demographics of the oil and gas industry. The boom and bust cycles of the oil and gas industry has led to a personnel problem referred to as the Big Crew Change (Schrader et al. 2007). This problem came about due to the layoffs of the mid 1980s. Those market changes resulted in an industry where 20 % of employees have fewer than 5 years of experience, universities that had scaled down or eliminated programs are struggling to meet the renewed need, and regions like North America and the Middle East have a shortage of employees (Brett 2007). The industry has large numbers of employees near retirement and a large number of new hires, but fewer employees in the middle range. Current students also appear to be less likely to consider graduate school as the employment opportunities are very good with a bachelor's degree.

Comparing these demographics to the previous surveys on climate change might indicate the oil and gas industry may have a lower percentage of employees concerned about climate change when compared to other STEM-based industries simply because of the younger age of the employees and the smaller percentage of employees with graduate education. There also is the overriding question of how the actions and comments of industry leaders such as those cited above affect the perceptions of the average employee.

3.2 Studying the Influence of Occupation

To measure attitude about climate change, we surveyed engineers, scientists, and other related individuals. Effort was taken to ensure a significant percentage of respondents work in the oil and gas industry and a similar sized group of respondents who work in industries not connected to oil and gas. The target group had received an education in one of the STEM (science, technology, engineering and mathematics) disciplines. The target group also included both professionals with undergraduate degrees and those with graduate or professional degrees. No identifying information was collected from any of the participants; therefore, the research was classified as exempt by the Institutional Review Board (IRB) of Montana Tech.

The 20-question survey was distributed electronically through Survey Monkey™ and was emailed to professional organizations, college alumni, and other appropriate groups. The survey instrument focused on one issue: Will a professional working in the oil and gas industry look at climate change data differently than a professional with similar background working in other industries? Other attributes measured by the survey for the purpose of identifying correlations were the level of education, political viewpoint, level of engagement in the political process, religious viewpoint, and gender. Questions either were written by the authors or, where applicable, were taken from a list of non-biased questions provided by Survey Monkey™. The full survey instrument is included in the appendix, and main questions are highlighted below.

Two questions on the survey addressed the main issue directly. The first asks if the respondent works in the oil and gas industry, and the second asks: "Is there solid evidence of climate change?" Table 3.1 shows how responses to the second question were scaled.

Table 3.1 Responses to survey question 2

Response	Score
Yes – mainly because of human activity	3
Yes – mainly because of natural patterns	2
Maybe – evidence is mixed	1
No	0

Other related questions looked at the respondents' feelings about mitigation efforts, including whether government spending and regulations were at an appropriate level, and whether humans have the ability to mitigate climate change.

The survey was distributed by sending email links to the membership of various professional groups, and recipients of the email were encouraged to share the link with other potentially interested people. However, it has proven challenging to get a large number of responses especially from oil and gas industry employees, and only 38 responses have been collected. This could be due in part to the sensitivity of the issue and the lack of tangible incentive for participating. Therefore, this survey is still being offered, and a second review of the results will be conducted when the number of responses is larger to see if there are any variations in the conclusions.

3.3 Findings Suggest Education Level and Occupation Matter

3.3.1 Central Questions

The second question above had a mean response of 2.559 with a mode of 3, indicating that most respondents believed climate change was real and primarily due to human activity. When the responses were separated into the two groups, oil and gas professionals and those who work in other industries, the mean response for the oil and gas group was 2.4 and the non-oil and gas group had a mean response of 2.684. It is interesting to note that of 34 respondents that completed the question, the only *no* reply came from the non-oil and gas group. A histogram of the responses of each group is given in Fig. 3.1.

While the oil and gas group had fewer responses of 3 and a lower average score when the responses were scored as indicated above, a t-test showed that the differences were not statistically significant.

Another important question is: How concerned are you with the social and economic impact of climate change worldwide? The choices were *very* (scored as a 3), *somewhat* (scored as a 2) and *not at all* (scored as 1). In this case, the mean response of the non-oil and gas group was 2.84, and the mean response of the oil and gas group was 2.2. A hypothesis test shows that this is a significant difference.

The next result is the respondents' feelings about mitigation efforts. A number of survey questions dealt with this. These questions included the following:

- How well do you think the environment can recover on its own from problems caused by humans? (Various choices ranging from *extremely well* to *not at all well*)
- The amount of money the U.S. government is spending on reducing global climate change is: (range of choices)
- United States government's laws restricting pollution should be: (various choices ranging from *much less strict* to *much more strict*)

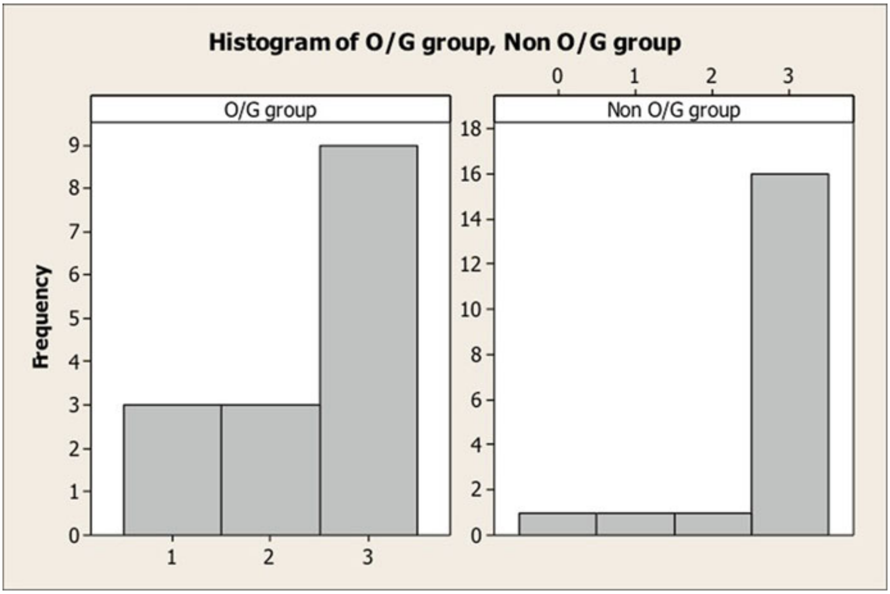

Fig. 3.1 Responses to the question: Is their solid evidence of climate change? A response of 3 is *Yes-mainly because of human activity*. The apparent difference is not statistically significant

The first question of this set was scored by setting the response of *extremely well* to a score of 5 and the response of *not at all well* to a score of 1. The entire group averaged a response of 3, comparable to a response of *moderately well*. Here again, there is a statistically significant difference when the groups are broken out into the oil and gas and non-oil and gas industries. The participants in the oil and gas industry were much more optimistic, with a mean response of 3.5, compared to the other group with a mean response of 2.42.

The next questions in this group looked at how the U.S. government should respond to the concerns, focusing on spending and regulations. On the question of spending, the respondents were asked about the level of spending related to mitigating climate change. A response that the government was spending *much too much* money was scored as a 5, with *much too littl*e being scored as a 1. Again, a statistically significant difference was observed in the two groups. The mean of the oil and gas industry group was 2.93, and the mean of the other group was 1.79 with a P-value of 0.022. A boxplot of the two sets of responses is given in Fig. 3.2.

The third question, regarding U.S. pollution laws, was considered next and the responses ranged from *much more strict* (scored as a 7) to *much less strict* (scored as a 1). Although the oil and gas group scored slightly lower with an average response score of 5 compared to 5.84 for the other group, this was not a statistically significant difference.

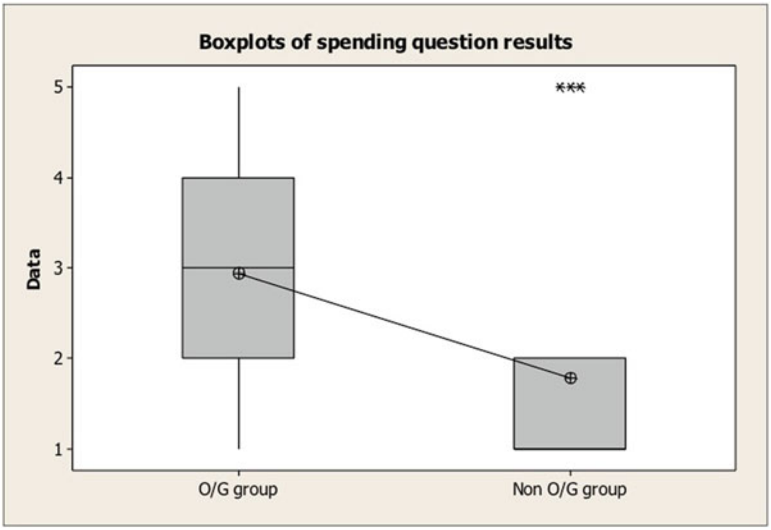

Fig. 3.2 Boxplot of responses to the question of government spending. A response of five indicates the government is spending much too much on climate change mitigation, a response of 1 indicates the government is spending much too little. *** Represents an outlier, a value that doesn't fit in the range covered by the boxplot

3.3.2 Education and Knowledge of Climate Change

While all respondents had college education, the percentage of graduate degrees was higher in the group that didn't work in the oil and gas industry. This may be due to the high number of jobs available in the oil and gas industry to candidates with bachelor's degrees, related to the shortages of workers.

Within the oil and gas industry group, it appears that those with a graduate degree are much more likely to attribute climate change to human activity then those with bachelor's degrees. Some 75 % of the oil and gas professionals with graduate degrees believed climate change is caused by human activity compared with 55 % of the group with bachelor's degrees.

The question, along with the directive "Check all of the statements you agree with," was followed by the responses below.

1. Climate change is a more descriptive term than global warming, as increased carbon dioxide emissions can cause a variety of changes in long term weather patterns
2. There is no consensus among climate scientists regarding the existence and/or causes of climate change
3. Deforestation is a significant contributor to climate change
4. Current weather events and overall trends are well within historical norms
5. Ozone depletion is a significant contributor to climate change
6. Increased atmospheric carbon dioxide provides significant benefits that outweigh the dangers

The goal of this question was to assess general knowledge of the topic as well as to measure the strength of certain misconceptions such as *warming will improve conditions on the planet*.

The majority of both groups selected the first statement and third; however, members of the oil and gas group were much more likely to believe that there is no consensus among scientists about global warming (40 % selected the statement), a belief that was held by 15 % of the non-oil and gas professionals. Similar trends were seen with statement four, a statement selected by more than 50 % of the oil and gas group and only 15 % of the other group. In an area of perhaps general concern, a majority of both groups selected the fifth statement: ozone depletion is a significant contributor to climate change, despite the science being fairly clear that the ozone layer stopped declining in the mid '90s while temperature continues to trend upwards (Yang et al. 2006). However, no respondents in either group selected the last statement, which indicated a belief that increased carbon dioxide was a net benefit.

3.3.3 Group Demographics

Other data collected from the survey included demographic information that may correlate or help to evaluate the other responses. These included questions of gender, political views, level of political participation, and religious beliefs. Both groups were predominantly male, with women making up 20 % of the oil and gas group and 37 % of the other group.

The oil and gas group tended to be slightly more to the right of the political spectrum with 33 % of the respondents selecting Republican, 27 % selecting Democrat, and the largest percentage, 40 %, selecting Independent. The non-oil and gas industry group was 68 % Democrat, with the remainder split evenly between Republicans and Independents. In both groups, a majority of respondents was interested in the political process.

The distributions of religious beliefs were similar between the two groups, although a higher percentage of the members of the oil and gas industry selected Christian to describe their religious beliefs (60 % versus 48 %).

3.4 Conclusion

While the differences in the responses of the two groups to the central question of the study, "Is there solid evidence of climate change?" were not significant, the remaining results point to a difference in how the two different groups view climate change science. The first group, professionals in the oil and gas industry with college educations tended to be more skeptical about climate change. The second group, college educated professionals in other STEM (science, technology, engineering and mathematics) areas were more concerned about climate change and more willing to address it.

Differences may be due to industry loyalty, but education level may play a role as well. A lower percentage of members of the oil and gas group reported having a graduate degree, and in the small group that did have such a degree, the differences in climate change attitudes seem to vanish. According to the college planning website, Campus Explorer, the recommended level of education for those wishing to enter the Petroleum Engineering field is a bachelor's degree (Campus Explorer n.d.), and schools like Montana Tech report very high job placement (currently in the 90 % range) of their Petroleum Engineering graduates. In contrast, the Campus Explorer site recommends a master's degree for Geoscientists. It is possible that the research requirements of a graduate degree better prepare students in all disciplines to evaluate scientific information and literature outside of their field. However, with the oil and gas industry booming, there is little motivation to enter graduate school, perhaps limiting the collaborative research between industries toward finding solutions.

In order to better understand the effect of industry affiliation on perception of climate change, the survey distribution will continue with a goal of a larger sample size that includes more oil and gas professionals with graduate degrees. Other correlations will be examined, such as how do those with graduate degrees compare with those with undergraduate degrees on all the survey questions. Correlations involving religious and political views and climate change will also be further investigated.

In summary, this study asserts a relatively modest thesis, on the basis of limited sociological inquiry. It asserts that preliminary survey results suggest professional affiliation in the oil and gas industry may correlate to some differences in survey respondent attitudes toward some aspects of climate change. The basis for this chapter's thesis is a 20-question, 34-respondent survey comprising various engineers, scientists, and other related individuals from within and without of the oil and gas industries. The results of the survey show differences in responses to some of the questions, which we have found to be statistically significant in some cases. Although both groups tended to acknowledge the existence of anthropogenic climate change on a roughly equal basis, differences existed in questions concerning the importance and potential effectiveness of human responses to attempt to mitigate climate change impacts. Generally, responses among the oil and gas professionals showed somewhat less confidence or urgency with regard to the effectiveness or need for government-led mitigation efforts.

This study is limited by two potential sources of error: (a) the small sample size of the survey and (b) the potential non-comparability of the samples, given that the non-oil and gas sample contained a much larger percentage of respondents with a post-bachelor's level of education. Both of these sources of error are significant enough that the experiment should not be relied upon to support any conclusion beyond that (a) the results suggest that further study may find a more significant distinction and (b) future studies should attempt to correct these sources of error by including a larger sample and attempting to include members of the oil and gas industry who hold post-bachelor-level degrees. As an alternative, future studies may attempt to include members of the STEM professions who do not hold advanced degrees in the non-oil and gas group.

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Part II
The Role of Science in the Conversation

Chapter 4
Science Advocacy and the Legal System: Is Life Cycle Assessment Unconstitutional?

Danny Cullenward and David Weiskopf

This chapter addresses the role of environmental science when climate policy is challenged in the United States legal system.[1] We focus on a recent court case contesting the use of Life Cycle Assessment (LCA) methodologies in California's state climate policy: *Rocky Mountain Farmers Union v. Goldstene* (2011). This case illustrates the importance of communicating environmental science within the legal system, a task that requires interdisciplinary collaboration between lawyers and scientists, as well as attention to principles of rhetoric. *Rocky Mountain Farmers Union* (*RMFU*) also demonstrates the potential for climate policy litigation to call into question basic principles in environmental science, especially those related to climate science.

As climate policy begins to evolve in the United States, we suggest there is a need for the scientific community to become more engaged in the legal system. Lawsuits from policy opponents will require judges to make decisions that turn on scientific methodologies, scientific evidence, and scientific judgment. Whatever the normative or scientific merits of the underlying policies, judicial decisions can have broad impacts, and ideally, they should be informed by the best available science. But judges are trained as legal experts, not scientists. Most do not have any expertise in environmental science; often, they have no training in science at all. Like judges, the lawyers who represent the parties are unlikely to have any scientific expertise. Thus, if the legal outcome of a court case turns on scientific concepts, the main participants are poorly equipped to address the substance of the case.

[1] This chapter is adapted from Cullenward and Weiskopf (2012).

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One solution is for scientists to participate in the cases as *amici curiae*, or friends of the court, to provide a third-party perspective on technical issues. Admittedly, the idea is not new. Indeed, many scientists already have experience as *amici* in major federal cases addressing climate science. We suggest, however, that the need for these communication efforts is expanding into new areas and warrants increased attention from the scientific community.

In particular, high-profile legal cases give false comfort to the notion that federal courts generally understand and accept basic evidence in the field of climate science. For example, the Supreme Court ruled that the Environmental Protection Agency (EPA) must determine whether greenhouse gases are *air pollutants* under the Clean Air Act. *Massachusetts v. EPA*, 549 U.S. 497, 528–529 (2007). In response, the EPA found that greenhouse gases "may reasonably be anticipated to endanger the public health and to endanger the public welfare of current and future generations," a prerequisite for beginning regulation under the Clean Air Act.[2] Subsequently, the D.C. Circuit Court of Appeals found that the EPA acted within its authority when it developed regulations to control greenhouse gas emissions from stationary sources under the Clean Air Act. *Coalition for Responsible Regulation v. EPA*, 684 F.3d 102, 134–135 (D.C. Cir. 2012).[3] These cases might seem to indicate that the federal court system has accepted the basic findings of the climate science community, but unfortunately, that view is incorrect. The legal holdings in *Massachusetts* and *Coalition for Responsible Regulation* are actually quite narrow, focusing on specific aspects of the EPA's authority to regulate greenhouse gases under the Clean Air Act. As a result, the legal precedent is limited and will not automatically apply to judicial evaluations of other climate policy regimes.

In policy terms, the result of these cases is similarly underwhelming because the United States still lacks a comprehensive climate policy. Although the EPA has taken some actions to address climate change, many scholars doubt that the Clean Air Act is the best vehicle for comprehensively regulating greenhouse gas emissions (e.g., Nordhaus 2012). Should the federal government establish a comprehensive climate policy—either through the Clean Air Act or new legislation—litigation that implicates climate science will almost certainly follow.

Meanwhile, states are taking the lead on climate policy, and in turn, their opponents are developing new legal strategies to challenge these efforts. *RMFU* represents one such challenge, and as a leading case in this area, it will likely test the ability of states to act on climate. Because the argument in *RMFU* is based on a completely different legal theory than *Massachusetts* or *Coalition for Responsible Regulation*, the reasoning in these high-profile cases will not necessarily control the outcome—even though the

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[2] EPA (2009). EPA also established that greenhouse gas emissions from mobile sources in the United States contribute to the endangerment it identified, a related step required to regulate each category of emissions sources under the Clean Air Act. Following this finding, EPA established regulations for greenhouse gas emissions from light-duty vehicles in 2010.

[3] This case concerned the regulation of greenhouse gases under a separate section of the Clean Air Act that applies to stationary sources. The facts of the case are quite complex and concern a number of detailed aspects of administrative law; it could also be appealed to the Supreme Court. For an overview, see Danish et al. (2012).

issues in *RMFU* implicate the same basic scientific concepts that were previously reviewed by federal courts. As a result, *RMFU* presented a need for additional environmental science communication; more and better communication will surely be needed with each new state climate policy and each policy's attendant lawsuits.

In this chapter, we offer an example of interdisciplinary collaboration to provide judges with independent assessments of relevant environmental science. Working through the Stanford Environmental Law Clinic, the authors represented two groups of scientists before the Ninth Circuit on the appeal of *RMFU* (Brief for Ken Caldeira, Ph.D., et al. 2012; Brief for Michael Wang, Ph.D., et al. 2012).[4] Below, we describe the climate policy that was challenged, the district court's ruling, and the scientific issues on appeal. We illustrate a collaborative model for designing science-based arguments to assist judges in such cases, relying on the extensive peer-reviewed climate science and life cycle assessment literature. Finally, we close with some thoughts about the respective roles of environmental scientists and lawyers, and a plea for more collaboration between the two communities.

4.1 California's Low Carbon Fuel Standard

In 2006, California adopted A.B. 32, the Global Warming Solutions Act, which requires the state to reduce its greenhouse gas emissions to 1990 levels by 2020.[5] The *RMFU* plaintiffs challenged the Low Carbon Fuel Standard (LCFS), a part of A.B. 32 that addresses the greenhouse gas emissions intensity of transportation fuels. For context, the share of greenhouse gas emissions from the transportation sector is shown in Fig. 4.1, and the relative contribution of the LCFS towards the state's overall emissions reduction plan is shown in Fig. 4.2.

The California Air Resources Board (CARB) administers the LCFS and sets the associated regulations. Under the LCFS, the average greenhouse gas emissions intensity of transportation fuels sold in California must decline by 10 % by 2020.[6] Essentially, the LCFS is a cap-and-trade program: regulated entities can exchange credits or debits for emissions reductions between one another, a feature that provides additional compliance flexibility.

To establish the emissions profile of transportation fuels, CARB assigns an emissions intensity factor to each type of fuel sold in the state, expressed in gCO_2e per MJ of fuel energy delivered to the vehicle. Crucially, these emissions factors are developed using life cycle assessment methodologies. In its formal

[4] The briefs are available on the Ninth Circuit's PACER document system, which unfortunately charges users for viewing these public documents. Digital copies are available from the authors by email, or from the Environmental Defense Fund website: http://blogs.edf.org/californiadream/2012/06/25/outpouring-of-support-for-californias-low-carbon-fuel-standard/.

[5] Cal. Health & Safety Code § 38550.

[6] Cal. Code Regs., tit. 17, §§ 95482-95483.

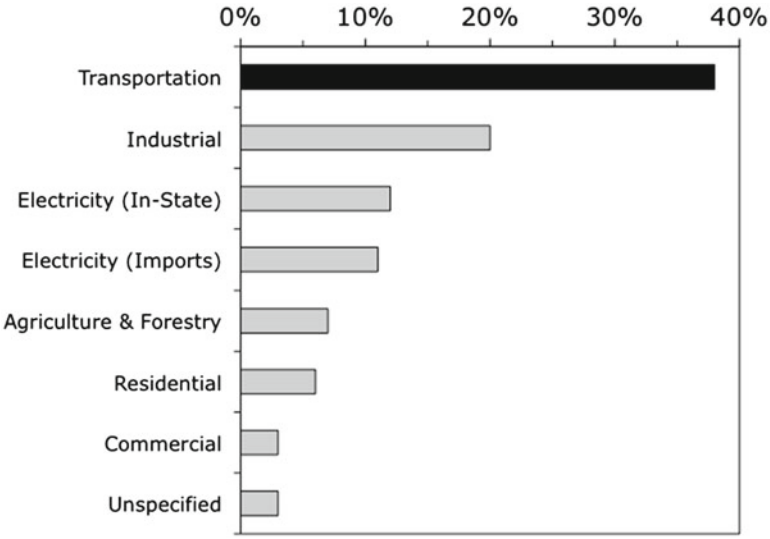

Fig. 4.1 California's greenhouse gas emissions in 2009 by sector (Source: CARB 2011)

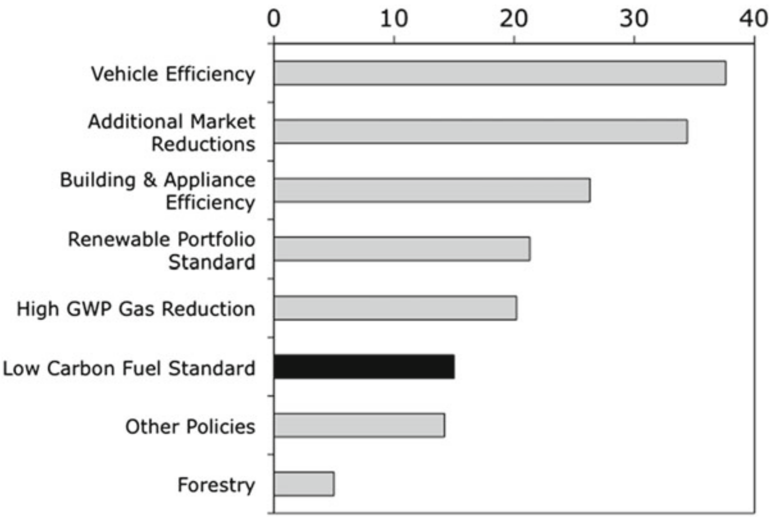

Fig. 4.2 Contributions to A.B. 32 emissions reductions (Units: million metric tons CO_2e avoided per year by 2020, calculated with respect to the emissions trajectory expected without A.B. 32 policies in effect. Source: CARB 2008)

regulations, CARB identified several dozen fuel production pathways, providing default emissions intensity factors for each. If a transportation fuels producer believes its emission profile is significantly different than the default pathway for its fuel type, it may submit an independent set of calculations to CARB to replace the default parameters.[7]

CARB's default life cycle emissions factors are developed using a model called CA-GREET.[8] Like any model of life cycle emissions from transportation fuels, CA-GREET estimates the emissions associated with the production of primary feedstocks, the transportation of these feedstocks to refineries, the refining process itself (including process energy), the distribution of refined products to market, and the combustion emissions associated with their final consumption. In the case of biofuels, CARB also estimates emissions from induced land-use change caused by increased demand for agricultural products.

From a physical science perspective, it is hardly surprising that these life cycle components describe sources of emissions that occur outside of California—but, as we discuss below, that fact raises important legal questions.

4.2 The Dormant Commerce Clause

The plaintiffs in *RMFU* are members or representatives of the oil, ethanol, agricultural, and trucking industries, along with two nonprofit groups that support expanded production of domestic fossil and biomass energy resources. These groups sued the State in Federal District Court, seeking to prevent the Low Carbon Fuel Standard from taking effect. In December 2011, Judge Lawrence O'Neill ruled that California's policy violates the United States Constitution under a legal doctrine known as the dormant commerce clause. California and a number of intervening environmental non-profit organizations appealed the ruling to the Ninth Circuit, which heard oral arguments in October 2012.

At its core, the dormant commerce clause doctrine is a part of constitutional law that concerns the legal boundary between state and federal authority. Its history begins with the Commerce Clause of the U.S. Constitution, which grants Congress authority to regulate interstate commerce. Since the nineteenth century, courts have interpreted this explicit grant of power to the federal government to also carry an implied limitation on the rights of states to enact laws that impact interstate commerce. Identifying the precise boundary is complicated, however, because states have traditionally had the right (both before and after ratifying the Constitution) to pass laws to protect the health and welfare of their own citizens, even if the implementation of these laws also affects interstate commerce.

Although the dormant commerce clause case law is complex, we can simplify its application here for the purposes of illustration (see Table 4.1). First, the appellate

[7] Cal. Code Regs., tit. 17, § 95486.

[8] The full model and documentation are available on the CARB LCFS website, http://www.arb.ca.gov/fuels/lcfs/lcfs-background.htm.

Table 4.1 Legal analysis of the dormant commerce clause[a]

	Judicial inquiry	Legal outcome	
Threshold question	Does the policy discriminate against interstate commerce?	If yes:	Apply test #2 (More strict)
	Facially;	If no:	Apply test #1 (Less strict)
	Purposefully;		
	Or in effect.		
Test #1 *Balancing test*	Do the local benefits outweigh the incidental burdens on interstate commerce?	If yes:	The policy is legal
		If no:	The policy is illegal
Test #2 *Strict scrutiny*	Is there another way to achieve the policy's purpose that is less discriminatory?	If yes:	The policy is illegal
		If no:	The policy is legal

In order to determine the constitutionality of California's Low Carbon Fuel Standard, a judge first asks whether the policy discriminates against interstate commerce, either on its face, as its purpose, or in its practical effect. The outcome of this inquiry determines which test the judge will apply to review the policy. Please note that this is a simplified illustration of the legal framework in the case

[a]In addition to stylizing the analysis in this table for clarity, we have excluded the extraterritoriality issue because the judicial standards in this area of the law are somewhat vague. Practically speaking, if a judge finds that California's policy constitutes extraterritorial regulation, he or she is also likely to find evidence of discrimination. In any case, our efforts to explain the science behind life cycle assessment and climate mitigation should apply equally well

court must determine whether, in its view, the challenged policy discriminates against interstate commerce. If so, the court will apply a *strict scrutiny* test, which few laws survive. In contrast, if the court determines that the policy is not discriminatory, it will apply a more lenient *balancing test*. Second, a somewhat obscure line of cases approach the same set of interstate commerce issues in a slightly different way, flatly prohibiting *extraterritorial* regulation of activities that take place wholly outside a state's borders. If a court determines that a state policy regulates extraterritorially, it will also find that policy unconstitutional.

As this structure indicates, judges have significant discretion in choosing which test to apply, as well as how to apply it. In *RMFU*, the district court judge found that the LCFS *facially* discriminates against interstate commerce (see Table 4.2). As a result, Judge O'Neill employed the strict scrutiny test, found that less discriminatory means were available for climate mitigation, and ruled the LCFS unconstitutional. In addition, he also determined that the LCFS constitutes extraterritorial regulation because it uses life cycle assessment methods that measure greenhouse gas emissions that occur outside of California. This second finding is based on an area of the law that has not developed highly structured tests, and ultimately reflects the district court's judgment of the LCFS regulations as a whole. It served as a second, independent basis for Judge O'Neill's final disposition. *RMFU*, 843 F. Supp. 2d at 1105.

The stakes here are high, as the impact of this case will likely reach far beyond the LCFS. If upheld, the district court's reasoning could potentially be used to challenge other A.B. 32 policies, state renewable energy portfolio standards, and even any state-level use of life cycle assessment.

Table 4.2 Selected default parameters for ethanol

Ethanol process	Location	Default carbon intensity	Difference between locations
Dry DGS; 100 % Natural gas	Midwest	98.40	9.50
	California	88.90	
Wet DGS; 100 % Natural gas	Midwest	90.10	9.40
	California	80.70	
Wet DGS; 80 % Natural gas	Midwest	86.80	9.36
20 % Biomass	California	77.44	

Source: Table 6 in Cal. Code Regs., tit. 17, § 95486; *RMFU*, 843 F. Supp. 2d at 1087
District court Judge O'Neill made this figure from the infamous "Table 6" in the regulations, adding the rightmost column to highlight the fact that CARB assigns a higher emissions number to the same basic process for producing ethanol in the Midwest than it does for production in California. Consistent with conventional life cycle analysis principles, the differences in emissions intensities reflect the different fuel mixes and energy requirements associated with the varying geographic locations of an otherwise comparable production process. Essentially, Judge O'Neill focused on the outcome of the life cycle analysis, rather than its methods, when analyzing whether the policy discriminates against interstate commerce
Units: g CO_2e per MJ of fuel delivered to the vehicle

4.3 The Ninth Circuit Appeal

On appeal, a three-judge panel on the Ninth Circuit heard oral arguments in October 2012. The panel is charged with reviewing the case *de novo*, which means they must make an independent determination about the legal questions in the case, without any obligation to accept any part of the lower court's findings. Representing two different groups of scientists, the Stanford Environmental Law Clinic submitted two amicus briefs in support of overturning the district court decision and affirming the constitutionality of the Low Carbon Fuel Standard. The briefs, written by the authors of this chapter, employ a novel approach to interdisciplinary legal practice, which we describe here.

First, it is important to understand what role science plays in the legal issues at hand in the case. Whether or not the LCFS discriminates against interstate commerce, and, if so, whether this discrimination is a constitutionally valid exercise of the State's legal authority are not purely legal questions. How a judge will make this determination will depend on her understanding of climate science, life cycle assessment methodology, and the dormant commerce clause case law. It will also depend on the litigants' ability to persuasively communicate this information to the judge.

Because most lawyers and judges do not have any exposure to the scientific issues involved in this case, we perceived a pressing need to bring science to the courtroom. But effective scientific advocacy is no simple matter. If a lawyer who lacks technical expertise develops a legal argument about the science in isolation, the result will likely make a scientist cringe. Despite his or her best efforts, the lawyer will surely miss important details or incorrectly portray the certainty of scientific evidence.

Similarly, the scientist is poorly equipped to navigate the appropriate legal questions and may not be a skilled communicator in a setting that relies on rhetorical abilities. Starting from either extreme requires both lawyer and client to spend significant efforts educating one another, a time-intensive process. Effective scientific advocacy in a legal setting can therefore benefit greatly from an interdisciplinary model that best reflects the contributions of both lawyers and scientists.

We endeavored to embody this model in the briefs we submitted for the appeal. One author has a background in climate science and the life cycle assessment of biofuels; the other author completed graduate coursework in life cycle assessment methods. With this experience as a starting point, the initial brief-drafting process from our legal team resulted in a product closer to the outcome that careful scientific assessment would produce if the client scientists themselves had conducted it. This approach enabled the client scientists to serve in a role akin to peer review, better leveraging their time and expertise to produce briefs that are scientifically accurate and specifically targeted at the relevant legal issues in the case.

Our approach in this case was also somewhat unusual: the briefs present almost exclusively scientific information, citing only a small handful of traditional legal sources. The climate science brief relies on the Fourth Assessment Report from the Intergovernmental Panel on Climate Change, the National Research Council (2011) review of climate science, and the California Second Assessment studies published in *Climatic Change* (Cayan et al. 2011). It cites only one case, *Massachusetts v. EPA*, to bolster the argument that California should be able to respond to climate even though its actions alone cannot solve the global problem. The LCA brief provides a primer on the basic parameters of standard LCA methodology, with particular attention to establishing reasonable system boundaries in the assessment of transportation fuels. Among other sources, it relies on a definitive textbook in the field (Graedel and Allenby 2002), a government handbook on LCA (EPA 2006), and the ISO 14044 guidelines (ISO 2006). It does not cite any cases.

While the content of the briefs is almost exclusively scientific, each brief is tailored to the legal aim of addressing particular components of the dormant commerce clause test (see Table 4.3).

The first hurdle in overcoming a dormant commerce clause challenge is to avoid the application of strict scrutiny by demonstrating that the challenged law is not discriminatory on its face, by its intent, or in its effect. The primary goal of the life cycle analysis brief was to help the court understand that the identification of sources of emissions that may also be related to geographical location does not constitute discriminatory treatment. Rather, this identification is precisely *non-discriminatory*, insofar as it adheres to the standard life cycle analysis practice of setting system boundaries for the products being compared such that all analogous processes, inputs, and emissions are included, regardless of political boundaries. In the LCFS, the LCA methodologies apply equally to all fuel production pathways and emissions sources; the fact that the outcome of the analysis is not equal across all geographies is a natural consequence of LCA methods, and not evidence of any discriminatory appearance, purpose, or effect.

Table 4.3 Summary of arguments in the science briefs

	Climate science brief	Life cycle assessment brief
Threshold Question *Does the LCFS discriminate against interstate commerce?*	(Not addressed directly.)	Provides a primer on LCA methods and applications; Argues that the use of widely accepted LCA methodologies demonstrates that any potential burden on interstate commerce is merely incidental; Argues that LCA methods are inherently non-discriminatory with respect to political or geographic boundaries
Test #1 *Balancing test*	Reviews the California-specific climate impacts literature to establish the benefits (i.e., avoided harms) of climate mitigation; Argues that the marginal growth or decline of emissions affects the risks from climate change, whatever independent actions others take	(Not addressed directly.)
Test #2 *Strict scrutiny*	Explains that greenhouse gas emissions from each stage of the fuel production process contribute equally to climate change, wherever they occur; Argues that not counting known sources of emissions reduces the effectiveness of climate mitigation policy	Argues that there is no alternative methodological approach to evaluating the full emissions profile of transportation fuels

If the court determines that the balancing test applies, it will want to know what benefits the State expects. The climate science brief reviews the climate impacts literature applicable to California to show what harms are expected in a changing climate. According to the National Research Council (2011), each marginal ton of emissions increases these risks, and therefore each marginal ton of reduced emissions contributes to their mitigation. The brief notes that although California cannot solve climate change on its own, the State's emissions reduction targets under A.B. 32 are consistent with conventional global mitigation targets.[9]

If the court determines that the strict scrutiny test applies, the proponents of the LCFS must show that there is no less-discriminatory alternative to the challenged

[9] The one legal citation in this brief is to Massachusetts v. EPA, which discusses the same issue. In dicta, the Supreme Court's opinion endorsed the argument that a particular climate policy need not by itself stop climate change; reducing emissions at the margin will "slow the pace of global emissions increases, no matter what happens elsewhere." 549 U.S. at 256.

regulations. For this reason, both the LCA and climate change briefs address the necessity of the LCA approach. The LCA brief argues that a life cycle approach is the only valid way to measure the carbon intensity of transportation fuels—in other words, that one must count known emissions sources from the various stages of the fuel production process to meaningfully distinguish higher- and lower-carbon fuels. Similarly, the climate science brief argues that accounting for these various emissions sources is necessary to achieving the state's climate mitigation goals because emissions of greenhouse gases like carbon dioxide contribute equally to climate change wherever they occur.

Neither brief rests on the premise that the exact numbers and equations used by CARB in the LCFS are the only means by which the State could set its regulations. Instead, when the briefs argue that a life cycle approach is necessary, they are addressing a more abstract concern about whether alternative approaches are available to evaluate fuels on a greenhouse gas emissions intensity basis.

The legal meaning of whether an alternative approach is available is different than how a scientist might normally answer the same question. In *Maine v. Taylor* (1986), for example, the Supreme Court considered the constitutionality of a state policy banning the importation of baitfish. There, the State was concerned that imported baitfish contained invasive parasites that threatened native populations. The Court found that the state law facially discriminated against interstate commerce and applied the strict scrutiny test. Next, the Court had to decide whether Maine's response was the least discriminatory means available to protecting native baitfish. Experts testifying on behalf of the challengers stated that they believed sampling techniques could be developed to distinguish imported populations that were parasite-free from those that were not; although this practice had not yet been developed, the experts believed there was no reason it could not be. Nevertheless, the Court held that the "abstract possibility" of developing new methods does not make those methods available as a non-discriminatory alternative. 477 U.S. at 147 (citations omitted). Thus, the possibility of scientific or technological change should not matter for the application of strict scrutiny—instead, a court must evaluate the options available to regulator at the time of regulation.

Applying the reasoning in *Maine* to the design of the LCFS is instructive. If strict scrutiny applies to the LCFS, the court must ask whether an alternative regulatory approach is both available and less discriminatory. Our position in the case was that there is no feasible alternative that results in effective climate policy without implicating the same interstate commerce issues the plaintiffs raise. Because every marginal ton of emissions contributes to climate change, the LCFS must be able to characterize the net greenhouse gas implications of California's transportation fuel consumption if it is to effectively contribute to climate mitigation. This task requires measuring all known sources of emissions, no matter the particular policy approach employed by the state.

One could argue that alternative policy architectures are available, but all of these approaches raise the same interstate commerce issues that arise under the LCFS. For example, instead of employing a cap-and-trade approach to the LCFS, perhaps CARB could set consumption quotas for categorical fuel types, without reference to individual production pathways (e.g., specific targets for petroleum fuels, biofuels, and electricity); the district court even suggested California could impose a carbon tax. *RMFU*, 843 F. Supp. 2d at 1093–1094. But if an alternative policy regime were properly designed to achieve the planned emissions reduction targets under A.B. 32, CARB would still have to make some kind of life cycle calculation in order to set the appropriate parameters of the alternative policy. To achieve a given mitigation target, categorical quotas would have to reflect the regulator's best understanding of the full emissions profile of each fuel. Similarly, the regulator must assign an emissions profile to each fuel type in order for the tax to reflect the product's full climate impacts. At this time, there is no way of comparing emissions profiles of fuel production pathways, except to perform a life cycle assessment of some kind—either formally or informally, explicitly or implicitly. Because this problem cannot be avoided in the design of effective climate mitigation policy, it is a necessary component of any meaningful policy response.

4.4 An Open Door for Challenging Science?

As a matter of legal doctrine, *RMFU v. Goldstene* (2011) raises interesting questions about the ability of litigants to challenge scientifically complex policy regimes. Normally, these kinds of challenges arise under administrative law, rather than via the constitutional challenges raised in *RMFU*. The key difference between the two areas of law is that courts generally defer to administrative agencies' findings, whereas courts exercise their own judgment over constitutional claims. Thus, if *RMFU* results in a precedent that overturns the use of life cycle analysis at the state level under constitutional law, it could significantly expand the ability of climate policy opponents to litigate against future policy regimes.

Some additional background may clarify the point. In the administrative system, a stakeholder who objects to a proposed regulation has the opportunity to do so before the regulation comes into force. In many states and at the federal level, the government agency that wishes to promulgate a regulation is required to substantively respond to any public comment in the rulemaking process. Litigation is generally available only after a public comment process is unsuccessfully resolved, and in most jurisdictions, courts give significant deference to the regulatory agency. This deference reflects an assumption that the agency staff are likely to have technical expertise that the courts lack, which increases the burden a challenger must bear in order to succeed in a lawsuit.

In contrast, constitutional challenges do not necessarily require litigants to participate in the public notice and comment process. Instead, parties can challenge the constitutionality of regulations in the court system, bypassing the administrative review process, and placing technically complex matters directly before judges. But as *RMFU* illustrates, constitutional claims do not always raise questions of a purely legal nature. Indeed, we believe the outcome of the case will depend in large part on how the Ninth Circuit panel understands LCA and perceives its role in the policy world. If this case indicates a trend of challenging state and local climate policies using legal theories that place scientific controversies directly before judges, the need for more and better science communication will grow even faster. To the extent that climate policies develop sector-by-sector and state-by-state, rather than on a comprehensive national scale, the number of challenges and the corresponding need for effective science communication will only be greater.

4.5 Conclusion

Using the example of *RMFU v. Goldstene*, we have described how legal challenges to climate policy can implicate concepts in environmental science in unexpected ways. Although nominally a case about interstate commerce, *RMFU* is better understood as a complex set of issues that revolve around the use of life cycle assessment methodologies in state-based climate policy. The case will have profound implications for California's climate policy, and it will likely set a precedent that affects other state-based policies that rely on or incorporate evaluation of cross-border environmental impacts in their design.

This chapter also provides a case study on communicating science in the courtroom. We show how findings from the climate science community and an overview of life cycle assessment practices are relevant to the legal questions in *RMFU*. We also identify the basic elements of developing a science-based *amicus* brief, a process that the authors' prior experience in relevant scientific fields facilitated.

Of course, many environmental scientists already work with the legal community to produce high quality *amicus* briefs. For example, a group of prominent climate scientists submitted an *amicus* brief in *Massachusetts v. EPA* (2007), represented by top environmental law professors from around the country (Brief of Climate Scientists 2006). Some of their lawyers had previous graduate training in science, while others had significant experience in environmental law and policy, enabling them to effectively present their client scientists' arguments.

Our experience recommends only a modest reform to this model. We suggest that interdisciplinary graduate education can provide a forum for similar efforts, but at a much earlier stage of the participants' careers. If we are correct that environmental science is increasingly likely to come before the courts in a *bottom-up* climate policy world, there is a pressing need to train more scientists and lawyers in a collaborative model—and preferably in graduate school or immediate post-graduate training, rather than in the mid-to-late stages of one's professional career.

Fundamentally, we believe that the environmental science community should consider the legal system as part of the broader policymaking process and seek opportunities to contribute to relevant cases. In our view, the notion of participating in litigation as *amici* should be no more foreign than other accepted ways of engaging the policy process, such as testifying before Congress or preparing a research report for a government agency. Publishing review articles, assessments, and other policy-oriented findings are already important parts of the scientific process. But those findings will not reach a busy court unless the scientific community brings them to a judge's attention.

4.6 Postscript

On September 18, 2013, the Ninth Circuit issued its decision in *RMFU*. In a lengthy and detailed opinion, the appellate court overruled all of the parts of the lower court's decision that misinterpreted—or blocked California's ability to use—the best available science.

Notably, the appellate court reversed the district court on two important issues. The majority opinion found that CARB's treatment of ethanol was not facially discriminatory, and that CARB's use of LCA did not constitute impermissible extraterritorial regulation. Consistent with the scientific consensus that "[o]ne ton of carbon dioxide emitted when fuel is produced in Iowa or Brazil harms Californians as much as one emitted when fuel is consumed in Sacramento," the court concluded that California "must be able to consider all factors that cause [greenhouse gas] emissions."

Even the dissenting judge embraced a sound application of environmental science. Although Judge Murguia viewed the default LCA parameters for ethanol as facially discriminatory, her preferred remedy—individualized LCA estimates for each fuel provider—demonstrates how a reasonable difference of opinion about the legal questions in the case need not threaten the scientific integrity of climate policy.

Both the majority and dissenting opinions interpret the case's scientific issues in terms that suggest the interdisciplinary collaboration we describe in this chapter had a positive effect.

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Chapter 5
Reduction of Conflicts in Mining Development Using "Good Neighbor Agreements"

Alexandra Masaitis and Glenn C. Miller

During the last decade, the Mining Contribution Index (MCI) showed the substantial impact that mining has on national economies throughout the world. According to the World Bank (ICMM. The role of the mining in national economies 2012. p. #3). "In 2010, the nominal value of world mineral production was nearly four times higher than it had been in 2002". On the other hand, new environmental and social challenges for the mining industry in both developed and developing countries show the obvious need to implement *responsible* mining practices that include improved community involvement. In this chapter, we examine economic realities, impacts of mining, needs for regulatory enforcement, and principles of a Good Neighbor Agreement.

5.1 Economic Realities

Developing countries and countries with transition economies experience both positive and negative impacts from the mining industry. First, the obvious positive economic effect of the mining industry is evident in exports and infrastructure development, particularly in those countries where the mining income is managed for the public good. During the last few years of the worldwide economic crisis, the mining industry, unlike most other industries, has still generally offered a wide spectrum of opportunities to local communities as well as contributed to the sustainable development in those mineral rich regions. According to the International Council on Mining & Metals, 33 countries have the highest (20 %)

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mining contribution index in their respective national economics. The list embraces a broad range of countries that includes Australia, Chili, South Africa, Suriname, United Arab Emirates, and Zambia.

Microeconomic contribution to low and middle income economies includes: (a) employment (1–2 % from total employment), (b) national income (GDR and GNI) (3–10 % of total national income), (c) mineral taxation (3–20 % of government revenues), (d) mineral exports (30–60 % of total exports), and (e) foreign direct investment (FDI) (60–90 % of total FDI) (ICMM. The role of the mining in national economies. 2012. p. #18).

Alternatively, even countries with major mining industries such as BRICS (Brazil, Russia, India, China, and South Africa) indicate low realization of basic human rights for the people from mining communities. This includes the right for the clean environment, the right of access to information (the right to know), and the right of public participation in decisions on permitting of mines. People who live nearest to the mines become dependent on the economic benefits from the mining activities. The conflicts between human rights and environmental protection are pitted against the need for jobs, and human rights and the environment often lose when the only source of income for the whole family is the respective resource extraction industry.

5.2 Impacts of Mining on Communities and the Environment

Numerous worldwide examples show that people become *hostages* to the work place. For example, some of the unhealthiest cities of the Russian Federation depend on the very mining companies that create a living environment that is dangerous. Such is the case for Novokuznetsk city. With 301,100 ton of air pollution per year (Rosstat Collections 2010), it is one of the oldest cities in Kemerovo Oblast, Siberia, and one of Russia's largest metal and coal producing centers. Magnitogorsk city, in Russia's Chelyabinsk Region, with 231,900 ton of air pollution per year, is a city with one of the world's largest iron and steel producers (Rosstat Collections 2010).

The city of Norilsk, north of the Arctic Circle, has more emissions than any other city in Russia; atmospheric discharges amounted to nearly 1 million tons in 2010. According to the Annual Report by the Russian Geographic Society (2011), Norilsk City is the most polluted city of the Russian Federation, and for the last 10 years was the dirtiest Russian city. The reason for this dubious distinction is that Norilsk is home for the Norilsk Nickel Company—the world's largest producer of nickel and palladium, one of the leading producers of platinum and copper, as well as producer of various by-products such as cobalt, chromium, rhodium, silver, gold, iridium, ruthenium, selenium, tellurium and sulfur. The data shows that combined emissions from the Norilsk Nickel processing facilities in 2010 totaled 1,924,000 ton (Rosstat Collection 2010).

Moreover, Norilsk city has shocking living conditions that have existed for several decades; according to the Rosstat Collections (2010). The average life expectancy for men is 45 years and for women is 47 years. Emissions for the major pollutants are 4–5 times higher on average than maximum permitted concentrations (MPCs). For several pollutants, the relative concentrations were much higher. For nitrogen dioxide, concentrations observed were 25.8 times the MPCs in 2003; for sulfur dioxide, the concentrations were 35.6 times the MPCs in 2002; and for formaldehyde, the concentrations were 120 times the MPCs in 2005.

Without a doubt, levels of pollution in the Russian cities indicated above have a very negative impact on human health and quality of life for the residents of these mining communities.

There are many reasons for the lack of environmental and public health and safety of mining operations in many developing countries and countries with transitional economies.

Of primary concern, the mining industry in most developing countries and countries with transitional economies do not have an adequate environmental monitoring system in place. Regulations are often inadequate and enforcement often weak or effectively non-existent. Environmental staff members working for companies in such countries often appear to choose employer interests over environmental and public health safety. The threat of the loss of a high paying job at a mine is apparently sufficient to dissuade employees from pushing for environmental controls.

Additionally, financial penalties are relatively small, compared to investments needed for technological modernization and pollution control, and encourage continual release of pollutants.

Furthermore, many companies implemented the ISO14001:2004 system on paper, but it is not having an adequate impact on the increasing environmental safety. For example, Norilsk Nickel Company had implemented the ISO 14001 system in 2005. However, the levels of pollution and the catastrophic public health situation mostly remained as they were before adoption.

A final problem is that available internet resources regarding environmental problems in most developing countries and countries with transitional economies are limited. Thus, it is difficult to find useful information, particularly when environmental audits are conducted. Technical information on emissions is too often simply not available to the concerned public.

Examples of the Russian cities above describe a systemic crisis of environmental policies in the mining sector of developing and transition economy countries whose economies are based on exploitation of nonrenewable resources. It often superimposes environmental contamination left from the previous years of exploitation, when environmental protection was one of the least concerns for all parties involved. It is also worsened by the lack of insurance/bonding policies, lack of professional risk assessments, and by the lack of audit and monitoring that could determine the level of exposure of the local community and the environment to the contaminants released at the mine sites.

It would seem that changes are needed that could include the following:

1. Regional environmental management principles should be followed and based on the local conditions such as physiographic region, local population, and socioeconomic conditions of the area.
2. Risk management criteria should be instituted and based on public health data, both near and far from the operation, as well as environmental and biodiversity protection that focuses on waste management, long- and short-term rehabilitation/reclamation plans, and compliance with international standards and norms.
3. Regulatory mechanisms and appropriate economic motivation should be generated, including appropriate fines, designed to make mining operations more *environmentally friendly*.

All three need to be developed for each country, but they should all be based on international standards. Communities near these industrial complexes often lack the knowledge of what is required to improve environmental performance and also fear the loss of jobs if complaints are lodged.

Even in developed countries with active and important mining industries (e.g. Australia, the U.S., and Canada), the mining industry has related complications including interactions with aboriginal communities, information access, and legacy problems from historic as well as operating mines.

In the United States, several mining operations are located on or near Native American reservations. The proximity often creates difficulties for both sides. For example, legacy issues with radioactive contamination and drinking water quality still exist near uranium mining operations in New Mexico that have led to outright bans of uranium mining on tribal lands. According to a *New York Times* article,

> Using old lists of potentially contaminated structures, federal and Navajo scientists have fanned out to rural reaches of the 27,000 square mile reservation—which includes swaths of Arizona, New Mexico and Utah—to measure levels of radium, a decay product of uranium that can cause lung cancer. Of 113 structures assessed so far, 27 contained radiation levels that were above normal. (Frosch 2009, para. #10).

Native Americans have become distrustful of having mining companies explore on their lands due to legacy problems, despite the fact that more than 10 % of all US mineral resources are located on tribal lands (Silva 2012).

Another issue is the lack of information and communication between mining companies, their neighbors, and other groups interested in protection of health and the environment. While most states and the U.S. EPA are willing to distribute available information, the technical background required to understand the information is often lacking, particularly in poorly educated communities. The reasons are twofold. First, many rural communities often have an inadequate understanding of environmental safety issues even when information is provided and may not be able to properly interpret that information. Second, different jurisdictions (country, state, or province) have differing regulations on availability of information, as well as the convenience for the public to gain access to it.

Availability of information is critical for the public to understand the public health and environmental impacts of a particular mining operation. There are three general stages where this information is important. First are the pre-mine impact statements, often described in Environmental Impact Statements (EIS), Environmental Impact Assessments (EIA), Environmental Assessments (EA), or related studies. These documents are designed to analyze what the impacts of a mine will have on the community and environment including impacts on water, air, employment, transportation, etc. The second set of information is gained during the actual mine operations and includes data on water and air quality, releases that may have occurred, as well as changes to the plan for the mine that occurred after the mine was permitted. The third set of information should be available close to and following closure. This will include closure plans, any specific type of problems that require remediation and data on monitoring of closure success, as well as any water, air and reclamation information.

Much of this information is not easily accessible by the public who may be concerned about the mine, since it is commonly buried in the agency files and not readily available and easily interpretable. This information should all be uploaded onto the web so that the public has access to the information, as well as sufficient annotation so that the public can understand impacts from the mine.

Finally, even highly developed countries such as USA have work force job dependence. Mines often located in remote areas could be the only source of income for local communities. Just as it is true for the developing world, environmental issues often are ignored in the conflict between environmental protection and jobs.

5.3 Needs for Regulatory Enforcement

The solution to problems listed above should include four considerations.

First, countries with developing and transitional economics should adopt and implement successful environmental practices used in the mining sector of developed countries although differences in regulatory mechanisms need to be recognized. The successful implementation of protective environmental practices in the mining industry is of critical importance as it not only limits both local and trans-border pollution but also improves the chances for having a clean and healthy environment for the people regardless of their place of habitation. It is especially important to encourage implementation of high quality environmental practices in developing and transitional economy countries. Poor environmental practices in developing countries will lead to local environmental crises that could eventually spill into surrounding countries including the most economically advanced.

Second, appropriate and effective regulatory mechanisms are required for protection of human health and the environment. Nothing can substitute for a regulatory agency that is well staffed with competent professionals authorized to do the job by regulations, resourced sufficiently to conduct their regulatory assignments and allowed to function in the absence of political interference.

Third, it is necessary to develop GNAs, a recently evolving process that promotes environmentally sound relationships between mines and the surrounding communities. Progress should be made to modify and apply the resulting GNA formulas to developing countries and countries with transitional economies. This is particularly important for countries that have poorly functioning regulatory systems that cannot guarantee a healthy and safe environment for the communities.

Fourth, it is necessary to identify spheres of possible cooperation among mining companies, government organizations, and the Non-Governmental Organizations (NGOs). This cooperation should be used to develop international standards for the GNA, and to promote exchange of environmental information, and exchange of successful environmental, health, and safety practices between mining operations from different countries.

According to the International Council on Mining and Metals the last few years show changes in the relative importance of different countries among the top mineral producers (ICMM 2012). For example, Brazil, China, Russia, and India have seen an increase in value of mineral production, while South Africa, USA, and Canada reduced their relative positions. This dynamic shows a closure of the gap between mining sectors of developed countries and countries with transitional economies, which emphasizes the necessity to implement GNAs in all countries with every level of economic development.

The goal of the GNA is to have open access for the public to the safety, health, and environmental information pertaining to the mining operation, as well as to educate the local communities about safe and sustainable mining practices that promote mutual acknowledgment of the need to build a relationship amenable to each other's needs. Frequent conflicts between mining companies and surrounding communities lead to work disruptions or even mine closures and show the necessity of a less confrontational approach to environmental and social justice. Establishment of a GNA model for use in both developed and developing nations can decrease these conflicts in many cases. Because of the higher quality environmental standards already in place, this new approach perhaps should first be established in developed countries and then applied to other countries with less developed economies.

Good Neighbor Agreements do not have a long history in the US, but implemented GNAs appear still to be functional. According to the Natural Resources Law Center (Kenney et al. 2004), the United States has 11 GNAs that have been developed for the mining industry and other industrial companies. One of the first agreements that are still effective today, was signed in 1995 in California by the Union Oil Company, the Shoreline Environmental Alliance, and the Communities for a Better Environment. In 1997, in Nevada, a "Good Neighbor Project" (GNP) was implemented for companies that rely on railroads for chemical transport. This GNP was developed by Nevada Citizen Alert, the United Transportation Union, the National Environmental Law Center, and the Tides Center. It was designed to limit the hazards of rail transportation and improve safety practices by the nation's largest chemical hauler, the Union Pacific Railroad. The most famous and highly effective GNA was created in 2000 for the Sweet Grass community and the Stillwater Mining Company, which operates two platinum/palladium mines in Montana, USA.

5.4 Principles of a Good Neighbor Agreement

The Good Neighbor Agreement is a mechanism for establishment of environmental standards and a new type of dialogue, based on understanding of mining impacts and trust between the mining company and the community, promoting environmental protection and public health. GNA standards resulting from current research coupled with the international environmental standards can provide a basis for the future accessible interactive Internet model. This model could serve as a tool for independent technical scientific expertise and will provide strategies for the implementation of the GNA. The model will be an open resource accessible to all interested parties. It will provide information and strategy but will also promote public activity and community education.

The Good Neighbor Agreement currently evolving will address the following:

1. Provide an economically viable mechanism for developing a partnership between mining operations and the local communities that will increase mining industry’s accountability and provide higher levels of confidence for the community that a mine is operated in a safe and sustainable manner.
2. Create practices and procedures that encourage local communities to become active in understanding the mining venture and establish effective communication between the mine and the community.
3. Increase the diversity of people benefiting from the results of this research by providing standards that could be adopted in developing countries. A global interactive Internet based model based in the public domain, can assist in providing a mechanism to increase levels of environmental awareness and education.

General strategies for a successful GNA are described in several documents, including: “Evaluating the Use of Good Neighbor Agreements for Environmental and Community Protection” (Kenney et al. 2004), and materials from Fifth International Conference on Environmental Compliance and Enforcement (Citizen Enforcement: Tools for Effective Participation 1998).

The following general principles exist:

– A Good Neighbor Agreement is a contract between the mining company and members from the local community, NGOs, etc., that provides the necessary information for understanding the respective mine and provides a way for community participation in environmental protection and socioeconomic practices. This includes, but is not limited to, the descriptions for the environmental protection policies and practices that are required at mines, as well the information and understandable descriptions of waste management plans, plans for the corrective actions, the list of common permits from government agencies and descriptions how they are implemented in practice and how they support sustainable mining operations.
– “GNAs also “include provisions for public disclosure of relevant company information and stakeholder audits, whereby citizens engage in direct, on-site evaluations of facilities to identify changes that may be needed to ensure environmental

compliance, safety, and sustainability" (Citizen Enforcement: Tools for Effective Participation 1998).
- In addition, a Good Neighbor Agreement can provide a mechanism for communication between the mining company and the community and establish the mechanism for the public comments regarding mining activity that can be reviewed by independent environmental specialists. More importantly, residents should have a chance to participate in audits and plant inspections that include, but are not limited to: accident prevention, monitoring programs, emergency response, and regulatory compliance.

5.5 Conclusion

Successful implementation of a Good Neighbor Agreement (GNA) is dependent upon three important considerations.

First, the GNA should be the basis of communication between the mining operation and local community. The goal is to minimize the conflicts and disagreements between the community residents, environmental NGO's, and the mining industry.

Next, GNAs will not work in every situation, and require that both the mining industry and the *neighbors* are willing to participate in a cooperative manner. Failure of trust is likely to result in a failure of the GNA. Each GNA is likely to be different and as such will reflect concerns of the local community, addressing local issues with specific socioeconomic and geographic conditions and specific aspects of the mine being constructed. Legal enforceable agreements are generally going to be required.

Finally, the future model of a GNA can be utilized by communities in many locales and can be utilized whenever there is a need and willingness to create a working relationship between a mining company and a local community. The GNA must be used only in addition to the environmental protection documents and permits by the respective jurisdiction(s) and will represent a further assurance for both the community as well as the mining company. The model for a generic GNA (which currently is being designed) can be used in developing countries and countries with transitional economies and will play an educational role to show the points that may require special attention and be understandable by the community. However, implementing GNAs will probably occur initially in developed countries where regulatory programs exist and are enforced. Neighbors and NGOs are not regulatory agencies, and should not be put in a position of primary enforcement. The lack of strong regulatory agencies in developing countries can reduce the applicability of GNAs since reliance on a GNA for environmental protection is generally outside the bounds of what GNAs can do.

The Good Neighbor Agreement is a unique way to provide the benefits both for mining operations and the local community to provide a mechanism for development of trust and communication that offer the potential to protect both mining and community interests, and can possibly reduce conflicts in resource development projects.

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Chapter 6
Science Communication and the Tension Between Evidence-Based and Inclusive Features of Policy Making

Sarah Michaels, John Holmes, and Louise Shaxson

Effective science communication within the policy domain is becoming more challenging due to the increasing complexity of, and higher aspirations for, public policy making. Not only are policy issues becoming more multifaceted and interlinked, but certain features of modern policy-making salient to diffusing knowledge are in tension with each other. The causes and consequences of these tensions are rarely articulated, let alone considered with the intent of ameliorating the resulting impasses. Consequently, we explore the mounting tension between the demand for evidence-based policy on one hand, and for meaningful public input on the other.

Evidence-based and *inclusive* have been two of the nine features of good practice in modern policy making identified by the UK Government over the past decade (Bullock et al. 2001; Cabinet Office 1999). In this prescription, *evidence-based* requires that the advice and decisions of policy makers depend upon the best available evidence from a wide range of sources including stakeholder engagement; whereas, *inclusive* requires that the policy-making process takes account of the impact on and/or meets the needs of all people directly or indirectly affected by the policy, and involves key stakeholders directly (Cabinet Office 1999). The tension arises because the guidelines policymakers are bound to follow have not yet been reconciled with our improved understanding of the principles of modern policymaking (see Bochel and Duncan 2007).

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Although the prescription for *evidence-based* policy making includes a requirement to engage with stakeholders, it is typically realised in practice as a focus on analysis and the quest for a definitive truth in "sound" science. *Inclusive* policy making is typically concerned with engagement and recognising the legitimacy of a diversity of interests and views. These two features can therefore pull the policymakers and their supporting analysts in different directions, and require different skills and mind-sets. New methods of public engagement such as citizen juries and wikis tend to be considered as facets of the *inclusive* feature of policy making without necessarily being examined for the role they can play in support of the *evidence-based* feature.

To the extent that these two considerations are addressed, the consequent streams of activity tend to run in parallel. There is a tension between the demand for evidence-based policy on one hand and for meaningful public input on the other. This necessitates nimble and astute *tension brokers*, skilled in communicating science in the different contexts, and who have three primary tasks; knowledge brokering, reconciling different ways of knowing, and recognizing when reconciliation is not achievable and/or not desirable. Knowledge brokering involves facilitating the exchange of knowing with the intent of providing or creating understanding, that if incorporated into policy, would result in policies that reflect the most up-to-date, best available, knowledge of the issues involved and the qualifications that apply to that knowledge (Michaels 2009). Bringing together different ways of knowing in the policy context we are considering, is about enabling the reconciliation of the different ways of knowing associated with the two considerations of *evidence-based* and *inclusive*. Appreciating that reconciliation is neither universally feasible nor desirable is an essential prerequisite in understanding that not all discordant circumstances are malleable to worthwhile compromise.

We sketch out some of the more pressing consequences of the quandary of trying to satisfy, let alone maximize, evidence-based and inclusive considerations in policy making by selectively drawing on UK and US perspectives of incorporating science into environmental policy making. To better understand how we have arrived at this quandary, we begin by highlighting some of the key milestones, trends, and cultural dispositions that have shaped the recognition and demand for evidence-based and inclusive policy making. We then present a salutary tale of the UK Committee on Radioactive Waste Management's experience of trying to satisfy the conflicting demands for evidence-based and inclusive deliberations before considering how to address conflicting demands in the policy process. We emphasize the potential contribution of tension brokers, adept in recognizing the relative weighting of the demands in a particular policy process, and able to bring to it the requisite combination of skills.

6.1 The Two Considerations and the Resulting Tension

We begin this section by considering how science has been at the heart of what constitutes evidence. While the UK Government defined *evidence* fairly broadly as discussed above (Cabinet Office 1999), its expression in terms of the guidance given to policymakers has, we believe, resulted in a particular focus on that sub-set of evidence that is labelled *science*. UK Government initiatives have included the updating of guidelines on the use of scientific evidence in policy making (Office of Science and Technology 2000, 2005, 2010), the auditing of their implementation by Government departments and agencies (Office of Science and Technology 2001), and the installation of Chief Scientific Advisors in senior positions in Government departments. The percolation of these initiatives through to practice may be witnessed, for example, in statements of the Environment Agency (the main environmental regulator for England and Wales) that its decisions would be based on *sound science* (Environment Agency 2007). This focus on science has drawn criticism from some quarters that implementation was following an unduly narrow perspective (e.g. Hammersley 2005).

With regard to inclusivity, calls have continued to be made for a more inclusive process in the UK. For example, the House of Lords Science and Technology Select Committee (2000, p. 8) concluded that "direct dialogue with the public should move from being an optional add-on to science-based policy-making … and should become a normal and integral part of the process" (p. 8). Similarly, the Council for Science and Technology (2005) recommended that Government "now needs to generate a change in culture across government to ensure that non-expert and non-partisan perspectives are used effectively to inform the development of policies that are based on science" (p. 1). However, Bochel and Evans (2007) reviewing progress on *inclusion* in UK policy making since the Modernising Government White Paper (HM Government 1999) conclude that despite the generation of a considerable amount of guidance material on different approaches to inclusive policy making, "it remains a contentious and elusive aim" (p. 121).

In the US there is a prevailing belief held by those closely associated with the policy process in the rationality of science, and science is used as an important instrument in legitimating Government decisions (Jasanoff 1997). A ruling of the US Supreme Court in 1980 that regulators must demonstrate *significant risk* before regulating, and a 1983 guidebook from the National Academy of Sciences prompted the widespread adoption of scientific risk assessment as the basis for US regulation (Wiener and Rogers 2002).

However, those beliefs in, and requirements for, a scientific approach sit alongside a strong commitment to a pluralist democracy (Beierle and Cayford 2002) in which divergent opinions need to be expressed as a prelude to public action (Konig and Jasanoff 2002). US agencies consequently have historically had more formal procedures in place than their counterparts in the UK to ensure continual dialogue between decision-makers and their public clients and critics (Jasanoff 1997).

Governments in both the UK and US therefore continue to promote the two considerations in their policy making. Yet the contrasting cultural predispositions associated with the two considerations, two of which are sketched below, do not suggest an easily achievable middle ground:

- An evidence-based approach tends to emphasise a rational and analytical mode of policy making around clearly identified problems, which is conducted with a high degree of autonomy for evidence providers, and searches for objective truth and the one right answer. An inclusive approach recognises the interdependence of the players, focuses on engagement and integration, and accepts that the problem and the *truth* are to varying degrees socially constructed and that there may be many *right* answers.

- Emphasising an evidence-based approach in a rational and analytical mode of policy making tends to result in a process characterised by a progressive closing down of the way in which the issue is viewed and convergence on a particular policy option (Stirling 2005). Under such circumstances, expert elites may well retain their authority. In contrast, an inclusive process emphasising public engagement may be characterised by an opening up of the way the issue is perceived and lead to generating divergent policy options. The public/stakeholders do not want just to inform but to influence, and have expectations to do so. UK and US Governments have expressed concern that public engagement should be *genuine* (see, for example: House of Commons Science and Technology Committee 2007; US Environmental Protection Agency 2006). In these circumstances, science may well point in one direction, and the public another.

The collision of the contrasting expectations is illustrated by the experience of the Committee on Radioactive Waste Management in the UK. It reveals the perils of what in practice is something of a tightrope walk.

6.2 A Salutary Tale

The Committee on Radioactive Waste Management (CoRWM) was set up in 2003 by the UK Government to propose (by mid-2006) a technical solution for the long-term management of the UK's higher activity radioactivity wastes, and to inspire public confidence in that solution (CoRWM 2006). The Committee was therefore established to broker knowledge among science, public, and policy communities. Firmly embedded in its terms of reference was the tension between taking a rigorous scientific/analytical approach on the one hand, and achieving legitimacy and acceptance of policies through a process of political engagement on the other.

After some 30 years of failed attempts to establish a disposal route for radioactive wastes in the UK—attempts widely characterised as secretive and following a *decide-announce-defend* approach—the Committee recognised that it was starting from a low base in seeking to "inspire public confidence" (MacKerron 2007). A strong emphasis was therefore placed on engagement with the public, as reflected in both the makeup of the Committee and in its deliberative style of working (CoRWM 2006).

Within 12 months of the formation of the Committee two members had left (one resigned, the other was sacked) strongly criticising its approach to science: "…there can be no doubt that CoRWM's approach to science has been defective, even negligent, and continues to be so" (Ball and Baverstock 2006, p. 44). Also, an inquiry by the influential House of Lords Science and Technology Select Committee had expressed strong concerns about, "…the undue emphasis given to investigating methodologies of decision-making and public and stakeholder engagement at the expense of identifying the right scientific and technical solution", and, "…we have no confidence in the technical ability within CoRWM itself sufficiently to understand the science of some of the disposal options" (House of Lords Science and Technology Select Committee, 2004, pp. 4, 12).

While an increasing emphasis was placed on the science and expert input in the latter stages of the Committee's work, criticisms of its approach to science rumbled on (Collier 2005; Royal Society 2006). The problems were identified by the dissident (and departed) Committee members as rooted in "the age-old intellectual debate between rationalism and alternative social theories such as social studies, postmodernism and relativism" (Baverstock and Ball 2005, p. 316). In contrast such concerns were characterised by the Chair of the Committee in his lessons learned report (MacKerron 2007) as, "there is a view, especially in parts of the science community, that processes such as CoRWM's should privilege the role of science and be science-led, often interpreting 'science' in terms of a limited range of disciplines" (p. 9).

The experience of the CoRWM reveals that it is not enough to acknowledge the two considerations or even to attempt to address them in parallel. What is needed are ways to generate robust policy options which acknowledge, if not reconcile, however incompletely, the tension between evidence-based and inclusive policy making and allow for explicit choices to be made between the different options. In doing so, we need to acknowledge that not all policy issues share the same characteristics and by extension they do not need to follow the same procedures. Some will need "…a highly political, pluralist, bargaining and incrementalist approach… (while) …other issues—probably only a small minority—will both require and lend themselves to a much more planned or analytical approach" (Hogwood and Gunn 1984, p. 24). Determining the characteristics of a policy issue is an important prerequisite to determining what emphasis to place on the different policy processes to use (Shaxson 2008) and the organisational issues involved in implementing those processes (Shaxson 2009). The following section provides a first cut at what might be some of the options for doing so.

6.3 Tension Brokering

The two considerations, realised in practice as a thoroughly rational process based on scientific evidence and analysis on the one hand, and a more political process closely engaged with, and responsive to, the diversity of views and special interests on the other, generally follow parallel tracks. Activities to implement them co-exist, but there is little integration.

What are needed are effective and transparent processes for the constructive intertwining of the two considerations. We want policies and regulatory decisions that appropriately reflect our best understanding of the characteristics of the particular policy issue and the relevant natural and social systems. At the same time, we want these policies to be grounded in an appreciation of a diversity of viewpoints and interests, and engender acceptance and commitment to implementation. Various techniques and methods go some way to fitting the bill. Stirling (2005) categorises them according to whether they are used in one of two frameworks:

- a *closing-down* framework aiming to converge, consensually, on a particular view using such tools as citizen juries or consensus conferences; and
- an *opening-up* framework aiming to explore how alternative courses of action fare under different framing conditions using such tools as scenario workshops or deliberative mapping.

While there is no shortage of how-to guides on the above specific techniques (Stirling 2005 provides a useful summary) the use of these techniques in policy-making and regulation remains the exception rather than the rule (Council for Science and Technology 2005). One challenge is to embed these processes that achieve this rather delicately balanced intertwining of analysis and engagement in day-to-day policy and regulatory decision making activities. These processes and the circumstances that enable their use need further development so that a proportionate approach consistent with time and resource constraints can be taken. We should aim for a portfolio of processes so that approaches can be selected and tuned to the particular characteristics of the policy issue and the circumstances in which the portfolio's components need to be applied, for example:

- within *science*, processes which respond to calls to widen the range of inputs to include all relevant disciplines and non-mainstream views (European Commission 2002; Office of Science and Technology 2010), generating advice which is salient to policymakers while providing a balanced account of uncertainties and divergent views;
- within *policy making* the development of processes which enable effective communication and engagement between *science* and *non-science* bringing in values, interests, and political realities to the day-to-day business of Government; and
- a commitment to transparency in both science and policy making, to enable an intelligent and appropriately weighted account to be taken of a diverse set of inputs.

While the use of such processes may well become more routine as a result of their development, testing, and refinement, they will always require people working at the science-policy interface to tune them carefully to the particular challenges of the policy issue, and to implement them thoughtfully. There is a need to develop the function of *tension brokering* whose core is the accommodation of the two considerations through the intelligent application of these processes. Crucially, it is not necessary to be badged as *a tension broker* to act as one (see Jones et al. 2012): it is the functions people perform that are important, not the positions people hold in an organisation (Shaxson et al. 2012).

In enabling the process of accommodating the two considerations the act of tension brokering may be likened to tightrope walking, with the broker able to fall off on either side such as in the following examples:

- If too much emphasis is put on following an analytical and evidence-based process the resulting policy may lack legitimacy, and be hampered by a lack of support in its implementation.
- But if there is too much attention to inclusion, then the policy maker may be faced with an overwhelming diversity of contradictory views and may be unable to interpret them into a coherent set of understandings of the relevant natural and social systems.

While tension brokers work in the service of both evidence-based and inclusivity considerations in policy making, rather different mindsets and skills are required for each consideration. Evidence-based policy considerations may emphasize a role concerned with translation and dissemination of expert views, while inclusivity may be much more about soliciting a range of views that may differ in terms of substantive weight and how well articulated they are. Informing the knowledge brokering needs in evidence-based policy is a literature that considers moving the science from experts to decision makers (Bielak et al. 2008; Clark 2007; Holmes and Savgard 2008; Michaels 1992, 2005; Pielke 2007; Scott et al. 2006). Informing the inclusivity consideration is a literature that considers public participation and stakeholder involvement (Arnstein 1969; Beierle and Cayford 2002; Gavelin et al. 2007). Both of these literatures offer specific suggestions on the attributes and skills necessary to play the critical role of an intermediary in the policy process (see also Jones et al. 2012). For example, from the studies by Clark (2007), and Holmes and Savgard (2008), the distinctive skills of a knowledge broker include:

- being an effective mediator with good interpersonal skills;
- having a good sense of different arguments, able to see the forest from the trees, to produce a well-balanced synthesis or draw out competing lines of argument;
- being familiar and well connected with the worlds of research and policy, and able to see issues from both perspectives; and
- having a broad grounding in science.

But these skills are in short supply (Scott et al. 2005). Current initiatives to slim down administrations are exacerbating this shortage by reducing the numbers of science advisers, research project officers, and policy analysts in government departments and agencies who traditionally have performed significant elements of the knowledge brokerage role (Holmes 2005; Holmes and Savgard 2008). Also in short supply are stakeholder facilitation skills, especially in combination with technical expertise (Campbell 1997). Reversing these trends is essential if the two considerations are to be reconciled.

It is important to recognize that reconciliation is not always the desired end point. Not only do the evidence-based and inclusive approaches frame policy issues in different ways, different politico-administrative systems give rise to different ways in which science, policy, and politics contribute to decisions (Jasanoff 2005).

The function of tension brokering not only involves deciding in a given set of circumstances what is the appropriate mix of knowledge brokering and facilitation activities, it is deciding when reconciliation is not the productive way forward and deciding who has the legitimacy to make the choice about which side of the tightrope to jump off.

6.4 Conclusion

Communicating science in the public policy realm requires recognizing and addressing the tension between two considerations of good practice in contemporary public policymaking—evidence-based and inclusivity. When those developing environmental policy and regulation have pursued them in parallel, the results have been disappointing. Following this same track is likely to continue to be dissatisfying. Evidence is shifting from a traditional, single disciplinary perspective to the multi- and interdisciplinary perspectives consequent on engaging with a broader range of scientific expertise, to the yet broader and ill-defined spectrum of evidence arising from stakeholder engagement in an inclusive approach. Ensuring the *quality* of evidence and of supporting the integration of the different kinds of inputs in the decision-making process requires tension brokers who bring the best of what we know about knowledge brokering and facilitation to bear. At the same time they need an appreciation of when reconciling the two tendencies is impossible—when public policy must be built on choice between discordant alternatives, when science is one among competing considerations.

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Chapter 7
Science Communication and the Role of Scientists in the Policy Discussion

Kristan Uhlenbrock, Elizabeth Landau, and Erik Hankin

Would it be more accurate to say that science informs policy or is it more often true that policy informs science? Like any causality dilemma, trying to determine what came first or which is more prevalent is something of an exercise in futility. Nevertheless, societies depend upon the ramifications behind this chicken-and-egg question particularly in the literal Earth-shifting context of our time. This chapter will consider the two-way influence of science and society, focusing on how science and scientists can contribute to today's critical decisions and, just as importantly, to the decision-making process.

7.1 How Are Science and Policy Linked?

Science and technology have a tremendous impact on our modern society. Since World War II, great advancements in science and technology have stemmed from policy decisions and federal investments. In turn science has serviced society in innumerable ways. From exploring the cosmos to looking under a microscope, science and technology have led to life-saving discoveries and global solutions to challenging problems. The benefits, ideas, and explanations that science provides to our economy, public safety, national security, environment, and general way of life are invaluable.

Barke (1986) defines national science policy as the "federal rules, regulations, methods, practices, and guidelines under which scientific research is conducted" (p. 8). However, science policy is much broader than that and Burke goes on to say it "also refers to the dynamic, complex, and interactive processes and procedures—both inside and outside government—that affect how these rules, regulations, methods, practices, and guideline are devised and implemented". Barke delineates that the

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reach of science policy includes research, development, regulation, and "overall support of the national scientific community".

To be most beneficial to society, though, science policy should be seen as twofold: first, how policy shapes science; and second, how science informs the policy-making process. Science informing policy is similar to the concept of evidence based decision-making, which encourages research evidence to be used in discussing public policy and management decisions (Davies et al. 2000). In this chapter both aspects, science informing policy and policy informing science, will be discussed; however, emphasis will be placed on how science can contribute to the decision-making process.

The perspective of the authors is based upon their work at a non-partisan, non-profit scientific organization that is actively involved in bridging the science and policy communities, as well as previous experience of being scientists who transitioned into communication, outreach, and policy fields. Thus this discussion is informed by significant first-hand experience of what in public relations is called *boundary managers*, those who operate between (in this case) science and society and work to help interpret one to the other for mutual understanding and benefit. Working at the interface gives the authors opportunities communicating to various audiences and learning from these experiences on what works best. Continuous efforts to bring science to policy makers and keep scientists informed of the latest policies that affect their research or funding drives the effort of the authors to work at the boundary, educating on both sides. In addition, studying the role of scientists and their interaction with policy makers helps inform the best strategies for continued participation. The goal for this chapter will be to focus on the discussion of science policy in the context of the US Congress, though many of the ideas can be applied to other aspects of national, regional, and local decision-making. The authors will also highlight recent successes, which underscore the importance of various types of involvement and should resonate with the scientific community.

7.2 The Importance of Science in Policy

Every day, hundreds of people walk the halls of Congress. Not the policy makers themselves, or even their staff members, these are people who have something to say to those who write legislation. Doctors, union members, school children, paid lobbyists, and individuals from every other group one can think of, fill the halls of Congress daily, presenting information and discussing policy issues. Scientists are no different from the other groups represented in these hallways of Congress. Scientists must make their voices heard as frequently as everyone else in order to ensure that science is available and being utilized in the policy-making process. Funding for basic research and development, supported almost solely by the government, continues to move our scientific understanding of the world forward, and policy makers need to be reminded of these advancements that come from federally-funded science as well as who they can turn to when they need scientific information.

In addition to these basic needs, the socioeconomic consequences of issues that involve science are often high stakes for policy makers, and some have escalated dramatically through the years, especially topics such as climate change, water availability, hydraulic fracturing, and other societally relevant issues. Because many of these issues are complex, addressing them requires multifaceted analyses such as integrated modeling and prediction, assessment of risks and gains, calculating value, resource availability and limitations, and a variety of other factors—all needed to reach a sustainable solution. Those who make important societal decisions every day need relevant scientific information that is communicated in a clear, concise manner.

Some scientists shy away from being part of this dialogue because some science policy issues have become polarized in recent years. However, policy makers still need the most accurate, current, and applicable science to inform decisions. Scientists who discuss science with policy makers do a service to their community by bridging the gap between the scientific community and the policy community. Furthermore, policy makers must be accepting of science and eager to listen when policy questions would benefit from scientific or technical information. Despite differences between the groups, each has a crucial role to play in ensuring that science is utilized in the policy-making process.

7.3 Roles in Science Policy Discussions

7.3.1 Scientists

Scientists and the scientific community have a very important role in informing public policy. They can serve as a trusted resource of information that is unmatched by other voices. A scientist's research and findings can serve as a foundation to the decision-making process. However, there is a fine line that must be walked when scientists become involved in the policy-making process. The challenges and opportunities scientists face may be great and unanticipated. Nevertheless the authors will emphasize and discuss the importance of a scientist's role in policy discussions.

Scientific research must be maintained as an independent and unbiased source of information to uphold the integrity and quality of the findings. Additionally, the research must adhere to the scientific process and be free of value judgments. Nevertheless, science often can have policy implications, which are apparent based upon solid evidence and rational analysis. When this is the case, then scientists can serve an important role in communicating those ideas and offering expert advice, leading the way to a science policy discussion. In an article discussing science in the public interest, Griffiths (1993) states that science policy is "concerned with the incentives and the environment for discovery and innovation; more mundanely, science policy deals with the effect of science and technology on society and considers how they can best serve the public. As such, it is highly visible, value-laden, and open to public debate" (p. 3). When scientists' research has policy implications, they should not steer away from engaging in dialogue about their research and potentially providing expert advice on their topic. Ultimately, it is up to the policy makers to assess all the information and make the final call on what should be done to address the issue.

Former chairman of the US House of Representatives Science Committee, Sherwood Boehlert (2007) writes "scientists should participate actively, even avidly in policy debates, both as educated citizens and as professionals with relevant knowledge, and as beneficiaries of public support. Scientists ought to feel obligated to contribute to policy making in their communities, states, nationally, and even worldwide" (p. 2). One thing scientists must make evident when participating in a policy debate is whether they are speaking as a scientist versus a private citizen. A scientist is allowed to have an opinion; however, distinguishing between a scientist's personal opinion, ideology, or belief versus the scientific material being presented must be made clear for a productive conversation to occur. Additionally, scientists must also not mask scientific uncertainty in their research and be willing to clearly explain what the uncertainty means when communicating to policy makers. This will help scientists maintain their credibility and continue to be seen as a trusted resource.

There are few scientific studies that do not include calculating uncertainty, and when dealing with policy issues that involve society, there is often an additional level of societal risk that also must be determined, making the issue even more complex. According to Walker and Daniels (2001), sometimes a single scientific discipline may be insufficient or inappropriate to solve the entire problem or address the uncertainty of the conclusions; and researchers may be unable to answer the policy questions definitively (p. 264). It then becomes the role of the policy maker to find the experts to address all the questions needed to solve the policy issue. Scientists play a key role in these decisions, not only as a source of information on a topic, but also as a tool to help policy makers understand the deliberative process used in research, which in turn may be useful when developing solutions.

When scientists communicate with policy makers, they can either present only the science, including uncertainties and unknowns, or they can present scientific evidence that interprets what policy recommendations would be best suited based upon the findings. Some scientists believe strongly that one way or the other is the only correct way to engage policy makers. The authors argue that this decision is a fluid one to be made based on the individual scientist, their employer, the issue at hand, and the policy maker.

It is often the case that a scientist who becomes involved in public policy will face critique for doing so. As Oppenheimer (2010) said, "some scientists are fearful of treading into the contested terrain at all, while others do so but experience great difficulty in distinguishing its boundaries, and separating expert knowledge from value-laden, subjective judgments." However ominous it may seem for scientists to venture into the communication world, there is a great need not only for the dissemination of the information but also for science to be a regular voice in the conversation. Like with any qualification, training and experience are needed. The more scientists who acquire better and effective communication skills, then the greater the chance of scientific information being delivered accurately and with greater frequency.

Hassol (2008), an expert in climate science communication, likes to emphasize to scientists that it is not their fault if they are not the best communicators. “You were not trained for this role and generally are not rewarded for it. In fact, your scientific training tends to work against your ability to communicate simply and clearly to nonscientists, and there are disincentives for popularizing science” (p. 106). She emphasizes ways to become a more effective communicator by steering clear of jargon, words that mean different things to scientists and lay people, and utilizing metaphors.

Another difficulty a scientist will face when communicating research is the ability to provide enough evidence and support without inundating an audience with details. Condensing years of scientific research into concise and pertinent facts, which convey the complete message, is not an easy task. Oftentimes, decision-makers do not have the tools or expertise to draw conclusions directly from the research. Therefore, scientists can provide their knowledge and skills to draw accurate and useful recommendations that can be used to help inform a decision that must be made (Neal et al. 2008).

One more idea that requires further consideration of the role of scientists in policy discussions is the focus on *usable science*, or research that has direct applications to societal problems. As noted by Jacobs and Pulwarty (2003), “funding agencies and current review processes tend to perpetuate the view that science should not be ‘contaminated with’ social concerns. However, failure to appreciate the social context of decision-making has resulted in generations of scientific products that are rarely used” (p. 11). Scientists may not always be able to draw a clear link between their research and its societal-relevance; however, this does not mean that because a connection cannot be made, scientists should avoid working with practitioners or decision makers.

By building upon these relationships and having discussions about the needs and obstacles, scientists can have a greater understanding of what challenges society faces and how their research may contribute to solutions or what direction to take their future research. Science research and development that encompasses a more interdisciplinary approach, considered to be more *usable*, may provide additional scope to address challenges that policy makers are trying to tackle. In turn, this may provide more value to the science enterprise and help secure future funding.

Whether it is a national federal budget issue or a potentially devastating event that will impact a local community, scientists have a well-informed perspective that should be incorporated into the discussion. In doing so, one of the more difficult tasks a scientist may face is how to fine-tune their message into a succinct and meaningful point. Whether writing a letter or having a conversation, connecting the benefits of science to the economy, national security, public safety, or the environment will help give a more robust picture as to why someone should care. The authors put together a list of examples of simple messages with significant implications, as seen in Table 7.1, which scientists can use to illustrate their point.

What should also be considered is how a scientist can become a better communicator and in what ways can they make science more accessible to the public. Taking the time to practice how to communicate to non-technical audiences is

Table 7.1 Examples of scientific messages that May resonate with policy makers

Examples of simple messages that may have a resonating impact with policy makers	
Funding	Research is a long-term investment in our future. Deep cuts today deprive the innovators of tomorrow of the tools and knowledge they will need to keep the U.S. competitive in the global economy
STEM education	America needs a skilled workforce prepared for the jobs of the twenty-first century. To be economically competitive as a country, we must invest in science education to train the next generation of innovators and entrepreneurs
Jobs	Scientists and engineers make up only 4 % of the American workforce, but their work disproportionately creates jobs for the rest of the nation
Public safety	The Pacific West is part of a geologically active area, including the Cascadia subduction zone and the San Andreas fault system, as well as the Hawaiian hotspot. By identifying susceptible locations and structures, scientists can help mitigate the loss of homes and lives to earthquakes
Environment	Water quality in the Gulf of Mexico directly affects human and environmental health, as well as the economy, both in the region and nationally. Nutrient input from upstream agriculture practices and other human activities contribute to a dead zone, where dissolved oxygen levels are too low to sustain aquatic life and linked to massive fish kills. The Gulf of Mexico is a major source for the seafood industry, and supplies 72 % of harvested shrimp, 66 % of harvested oysters, and 16 % of commercial fish in the U.S.
National security	Sea level rise is expected to increase instability and conflict worldwide as people are displaced from coastal areas and food production drops. China and the Philippines alone have 64 million people in the lowest elevation zones, or three feet above sea level

essential. At times, the finer details of a scientist's research are needed; however, for more general conversation, keeping to straightforward and concise information will ensure interest does not wane. Although some scientists will be eager to learn better communication skills or enjoy the opportunity to interact with their legislators, not all scientists will, and that is the choice of the individual.

7.3.2 Scientific Organizations

Scientific societies and organizations can play a central role in science policy discourse in addition to an individual scientist's voice. Many scientific organizations, such as the American Geophysical Union (AGU) and the American Association for the Advancement of Science (AAAS), publish scientific journals, convene meetings and conferences, and have direct contact to member scientists, which give these organizations access to transformative and societally relevant scientific studies. Most policy personnel and public affairs offices at scientific organizations have knowledge of both the science supported by their organization and relevant policy. As a result, scientific organizations have a niche as the liaison between policy makers and organization member scientists and their research and can provide a collective voice for their members.

The majority of academic scientists spend much of their time performing research and advising and teaching students. Thus, many do not have the time to monitor policy developments or cultivate relationships with multiple congressional offices. Policy personnel at scientific organizations, on the other hand, can dedicate the necessary time and energy into tracking relevant policy initiatives and developing and maintaining relationships with policy makers and their staff. By devoting significant time to monitoring and acquiring information on bills and other policy measures, organizations can develop comprehensive advocacy strategies to inform their members of policy affecting their science.

Organizations will also be better prepared to answer questions and direct policy makers to the resources they need to inform their decisions. When creating an advocacy strategy for a piece of legislation, organizations will identify the key congressional offices or committees in the debate, communicate with those offices on the information needed, and also connect the offices to scientists in their respective districts or states to act as constituent resources for the policy makers. All of these avenues help bridge scientific information with the policy-making process.

It may not always be appropriate or timing may not permit scientific organizations to connect their members with policy makers. Therefore it is vital that policy staff at organizations have a good understanding of the science represented by their members, so that the staff may directly inform legislators. Organizations may also develop resources, like fact sheets or position statements, to aid in educating policy makers and providing a significant scientific voice to a science policy debate. Scientific organizations have a responsibility to their members to adopt positions of advocacy on relevant science issues based on their intrinsic merits and need.

Organization positions may be used by members of Congress as evidence of scientific consensus and understanding during policy debate, making them a vital tool for societies to employ to affect policy. It is integral that scientific organizations not take or advocate public positions on ideological issues or issues that go beyond the range of expertise for that organization or science. In representing tens of thousands of world-renowned scientists, scientific organizations have an immense database of qualified experts to serve as a resource to policy makers and contribute to the science policy discussion. Their roles as a liaison between scientists and policy makers, and the voice for their membership are fundamental in the science policy debate.

7.3.3 Policy Makers

Policy makers have a difficult job to efficiently assess the vast array of knowledge available at their disposal to craft and implement policies that may have long lasting and far-reaching impacts. In addition to the wealth of information available, policy decisions are complex in scope with various components framing the final decision, which may include, but is not limited to, economic implications, short-term and long-term risks, regulations, regional and local considerations, welfare of society, and available resources. With an abundance of constituents and stakeholder interests at play, policy makers hear from many sides that have a stake in the outcome of a policy decision. Finding a balance of fulfilling the duties to serve the public, as well as the interests of their district or state, can be a challenging task.

Scientific information is inherently complicated, sometimes having taken many years to research, and collect and synthesize data; therefore, policy makers need to be careful to not over-simplify the information they receive. For many technical policy questions, there is regularly not a single answer, evidence-based solution; therefore, not all science can be boiled down to a single-bullet talking point. Science can support recommendations, findings, and options; however, the majority of the time the question being asked is a policy-framed question. When this is the case, utilizing the scientific information presented is important, but must not solely be used as the all-encompassing solution. The role of the policy maker is to determine how the scientific information presented can fit into the larger question and what other pieces are needed to have a well-informed piece of legislation.

Policy makers must also be vigilant in using scientific information for the benefit of formulating a decision in policy debate, rather than politicizing an issue or manipulating it to support an ideology. The misuse of science can lead to mistrust, an inaccurate response to address an issue, or other unintended consequences. Furthermore, when policy makers use evidence or scientific information in a selective or fragmentary manner, such as only using evidence which supports their claim, then they run the risk of not telling the full story of what the scientific research suggests. Misinterpreting scientific results or uncertainty can be dangerous to the economy, the health of the public and environment, as well as national security; therefore, policy makers must strive to avoid this situation.

Often the value of basic scientific research and development, which can lead to future breakthroughs that benefit society, has been underestimated. One possible reason for this is the composition of Congress. If one looks at the roster for the 113th Congress, the lack of those with scientific training is apparent. Out of the 533 total members in both chambers, only 37 have any degree of scientific or engineering backgrounds. A breakdown of these 37 members displays 3 medical professionals and 1 engineer in the Senate, and 29 medical professionals, 2 engineers, 1 microbiologist, and 1 physicist in the House of Representatives.

With this visible void, it is essential that scientists learn to communicate with non-technical audiences, and policy makers strive to obtain the relevant science and technical information they need to inform their decisions. Policy makers must connect with the scientific community and see them as a resource to aid in their decision-making process. There are a variety of ways to do this, including contacting scientific organizations that have direct access to the top scientists in the fields, utilizing local universities, businesses with scientists on staff, and national laboratories commonly found in their state or district, or by hiring staff with a scientific background or hosting a science fellow.

7.4 Important Issues and Recent Examples

Recently the AGU put together a number of opportunities for scientists to become involved in the science policy dialogue. Here are some examples and studies from scientists' interactions with the public policy process on some of the important issues to the science community. In 2012 the budget crisis, known as the *fiscal cliff*, was dominating every major US news headline due to the resounding effects it would have on U.S. households and the economy. The *fiscal cliff* was in essence the combination of expiring tax cuts and the large across-the-board cuts to federal spending, known as sequestration. The peak of the negotiations for a fiscal policy deal occurred during December 2012. Utilizing the AGU Fall Meeting, a conference of over 24,000 Earth and space science professionals and students, AGU policy staff implemented a communications strategy to highlight the current negotiations, portray the importance to the science community, analyze the impact of cuts to research and development, and provide options and encouragement for scientists to get involved.

The strategy to communicate the information regarding the *fiscal cliff* budget crisis included multiple presentations, a scientific poster, electronic communication via a smartphone application and digital signs, and an organized listening session to a White House conference call discussing the impacts of sequestration to the science and technology community. In the end, over 280 scientists contacted their legislators and gave testimonials to the importance of federal funding to science. For example, Kristine Sigsbee (2012) a scientist wrote,

> The University of Iowa has a long history of excellence in space science research, going back to James Van Allen's discovery of the radiation belts using data from Explorer 1, the first U.S. satellite. Scientists at the University of Iowa are still engaged in ground-breaking space science research and the development of spaceflight hardware for upcoming NASA missions. Most of these scientists and engineers are not faculty members and are funded solely through Federal research grants and NASA contracts. They do not generally receive private funding or state funding to support their work. Cuts to Federal science funding would jeopardize their jobs and could end the space science programs at the University of Iowa forever. Very few university programs around the country have the capability to develop spaceflight hardware for NASA satellites. Cuts to Federal science funding will place this program and others like it on the chopping block, reducing our Nation's future spaceflight capabilities and our ability to compete with the growing spaceflight efforts of nations like China.

Similarly, in October 2011, an email campaign was sent to AGU members who lived in specific districts and states. The purpose of the email campaign was to gather signatures for letters to be sent to members of Congress who served on the *Super Committee*. The *Super Committee*, or formally the Joint Select Committee on Deficit Reduction, was formed after passage of the Budget Control Act of 2011 and was composed of 12 Members of Congress, with three members from each party from the House and the Senate. The bipartisan committee formally had until 23 November 2011 to give its report to Congress, but was unable to reach an agreement. Due to the failure to strike a deal, sequestration was mandated, resulting in $1.2 trillion of across-the-board cuts to federal discretionary spending.

The cuts were originally scheduled to occur over 9 years beginning on 2 January 2013 (note: at time of publication sequestration has been delayed until 1 March 2013 and negotiations are ongoing). Over 1,200 AGU scientists signed a letter voicing their concern over sequestration and the cuts it would cause to federal scientific research spending. Due to the efforts of these AGU members, and others who spoke out about the importance of federally funded research and development, many Members of Congress support finding a different approach to address the national deficit. Many Members of Congress are aware that implementing these cuts would have a drastic impact on the scientific enterprise and economy of the United States, and thus have voiced their concerns. Senator John Thune (R-SD) (2012) stated during the negotiations, "We are repeatedly reminded by all the experts that if we don't deal with this issue of the fiscal cliff, that it's going to have a devastating, catastrophic impact on our economy, on our national security, on our country, on the American people".

Acting when an important issue comes up is important, but even more valuable is forming a relationship with a congressional office or committee. It is an excellent way to become a resource for policy makers and typically will take more than one meeting or correspondence. In 2012 AGU, in collaboration with the National Academies of Science, American Geosciences Institute, and the American Society of Civil Engineers, organized a congressional briefing on the preparedness of the U.S. to tsunami risk and response. In addition to the briefing, the expert speakers (two scientists and an emergency manager) visited with legislators involved in appropriations and reauthorization of the Tsunami Warning and Education Act. The meetings and the briefing set the stage for future dialogue, which ended with the scientists having direct input into the language of the bill and being called upon for their expert advice.

7.5 Getting Involved

AGU can serve an important role as an international scientific organization representing over 62,000 Earth and space scientists; however, the distinct voice of a scientist to his/her legislator carries just as impactful of a message. Additionally, constituent scientists can serve as resources and experts in their particular fields for their legislators. There are various opportunities for scientists to expand their communication skills and get practice meeting with legislators at events hosted by AGU and other scientific societies throughout the year.

One series of these events, Congressional Visits Days, provides scientists training and tips on how to fine-tune their communication skills, as well as information about legislation. Following the training, scientists go to meetings with congressional offices and committees to discuss their science. A participant stated after a Congressional Visits Day in 2012, "I realize that the complicated messages of science have to be short, to the point, meaningful, and repeated with time. Engaging representatives repeatedly is part of the long-term strategy to be effective." Many participants find the opportunity to be in contact with their legislators as invaluable, and continuing to develop relationships as an important and necessary step that will not be accomplished with just one visit.

Another way scientists can get involved in the policy discussion is by attending conferences, which focus on the intersection of science and policy. Events such as the AGU Science Policy Conference, American Association for the Advancement of Science Forum on Science and Technology Policy, and the National Council for Science and the Environment National Conference provide the opportunity to learn about, present, and discuss some of the most pressing science policy issues. Participants also get a chance to network with other scientists, professionals, and policy makers to explore ideas and communicate science for decision-making. The outcome of these types of meetings helps to elevate the presence of science for complex decisions.

Scientists, like most people, have full-time jobs as well as resource constraints that may not always permit them to travel. However, this should not deter their involvement in the public policy conversation. Throughout the year U.S. Senators and Representatives return to their home states and districts to work, including the whole month of August. This is a great time to establish relationships or build upon existing ones to discuss the important science research that's happening in the district and state. Also, there is the opportunity to invite an elected official to visit a laboratory, school, or field site. For many legislators and their staff, such visits are a welcome respite from the norm. Getting involved is important at both the national and local levels. In addition to forming a relationship with a congressperson, local and state public officials also impact science and would benefit from getting to know their local resources.

Communication with the media is another venue for educating policy makers as well as the general public. The news is full of stories on important issues that would benefit from a scientist's voice. Spreading the message about the importance and impact of scientific research and development and its benefits to the public can be accomplished by submitting a letter to the editor of a local newspaper or other media outlet. This is a great way to communicate to a broader audience. A letter to the editor is typically submitted in response to a major, newsworthy issue that has been covered by a media outlet. Letters to the editor can be submitted by anyone, though not all submitted letters will be printed. A letter should offer a perspective on a specific issue that has, or has not, been covered by the outlet. When they are printed or posted online, letters to the editor are often presented in groups, representing both sides of any given argument—this balance of opinions is a staple of good journalism and should not be seen as a critique of a scientist's effort.

An additional option is writing an op-ed piece for a local newspaper. The timing is not as limited as a letter to an editor and typically the goal of an op-ed is to draw attention to the importance of a particular scientific issue that affects the community or region. It is helpful if the piece can be linked to a current or specific event. When writing an op-ed, or letter to the editor, it is best to keep it simple, relevant, short, and have a hook that translates into why people should care about the issue.

One more way to get involved in science policy is through affiliation groups within larger scientific society. Many scientific organizations, including AGU, have these affiliations in which scientists can associate based upon their interests and background. For example, AGU's Societal Impacts and Policy Sciences focus group connects scientists with others who have similar interests in science policy. Affiliations with these groups provide scientists with opportunities to learn and interact with a larger network to enhance discussions and encourage collaboration. Participation within groups can also bring about leadership opportunities and access to other ways of getting involved.

7.6 Conclusion

From the devastating effects of cigarette smoking on human health to understanding the impacts of sea level rise on coastal communities and infrastructure, science is the common denominator to help policy makers reach the most informed policy decision. Although the role of science in policy-making is sometimes unclear and possibly strained, this should not deter the exchange of scientific information. Challenges and limitations will likely arise as scientists and scientific organizations become more actively involved in communicating in a public policy discussion. However, the benefits of this communication are immeasurable. While many may reasonably view the recent politicization of science as detrimental to the science itself, the politicization does provide a catalyst for more scientific input in the public policy discussion.

Scientists cannot sit idly by while their hard work and research is attacked by those with ulterior motives—intensions beyond the intellectual merit of the science. Scientists must also realize that they are just one of many stakeholder voices, and policy makers will assess a variety of factors before making a decision. By educating legislators, the media, and general public about their research and the strength of scientific review, scientists, along with the support of scientific organizations and policy makers, can use the results of their research to benefit the public and the Earth and provide solutions to challenges facing society today and in the future. Choi et al. (2005) make a valid point that, "Good science does not always guarantee good policy; bad or even no science does not necessarily lead to bad policy" (p. 634). However, the authors stress that more concise and constructive communication between scientists and policy makers will allow for more informed policy decisions.

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Part III
Friending Earth via Social Media

Chapter 8
Transmedia Storytelling in Science Communication: One Subject, Multiple Media, Unlimited Stories

Kevin Moloney and Marijke Unger

The twenty-first century has brought a Cambrian Explosion to communication—an evolutionary burst of new media options. Since the dawn of the Internet Age, the channels through which we communicate have multiplied and morphed, and that presents interesting advantages for the science communicator. More channels that reach constituents more directly are available than at any other time in history. Communication technologies that were once the tools of only a select few are now at the fingertips of the masses. Yet those changes are only part of the story. Where channels of communication were once largely one-way, feeding information from the top down and often controlled by gatekeepers, they now allow and encourage two-way conversation between all involved. Where an audience once relied on relatively few sources of information, the public now has a seemingly endless array of professional and amateur media with which to engage. "The people formerly known as the audience," as Rosen (2006) describes them, have dispersed across a diverse and dilettante mediascape and expect to have a part in a global conversation.

These changes are old news even to a long-term resident of an Antarctic research station; many communicators and educators have embraced the possibilities. Messages are distributed in digital and analog forms through legacy and new media in ever more social ways. The entertainment, public relations, and advertising industries model an emerging storytelling technique, *transmedia storytelling*, that uses the advantages of new media, legacy media, audience participation, and investigative curiosity. These on- and offline tools help to find dispersed audiences and to engage them more deeply. Fans of an entertainment franchise find the story not just in one medium—cinema, for example—but across an array of professional- and amateur-created content. However, not as many in the science, education, or

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journalism communities have changed the structure of their storytelling to fit this new age. Rather than adapting communication to fit this new structure, often twentieth century communication styles are merely superimposed on twenty-first-century channels. The new media landscape demands a new approach to media.

In transmedia storytelling, a story unfolds not only through the digital innovations at the heart of today's media evolution, but also in traditional and nontraditional analog media. Transmedia storytelling uses multiple media simultaneously in an expansive way to better tell a single, complex story (Jenkins 2003). Each medium has distinct storytelling advantages. For example, video and animation illustrate action and process, text provides in-depth background, and games describe systems. When done well, transmedia storytelling has helped bring to film, television, and music franchises an enduring involvement and commitment from their fans. By adopting methods of transmedia storytelling, science communicators and educators can engage relevant publics, offer deeper and more valuable participation and interaction, deliver complex stories with deeper context, and find the public in that dispersed, diverse, and dilettante mediascape.

In this chapter we explore transmedia storytelling, outlining various means of presenting information about the geosciences, climate change, and computational science. We conclude by illustrating this approach using a recent project at the National Center for Atmospheric Research. We discuss our use of video, mechanical and digital interactive elements, animated movie segments, web-based content, photography, scientific visualizations, printed material, and docent-led activities.

8.1 Background of Storytelling

We are a storytelling species. Fisher (1987) coined the metaphorical *Homo narrans* to illustrate how entrenched storytelling is in human communication (p. 62). Storytelling, as it is usually seen as *spinning a good yarn*, has had a difficult relationship with scientific communication where technical discourse has long been valued. Earth sciences, built on careful and empirical research, are frequently delivered as a clear and direct reporting of facts. However, Fisher argues that "Humans as rhetorical beings are as much valuing as they are reasoning animals" (p. 105). The fidelity of any information resides for us in how well the story rings true. Narrative stories appeal to the imagination, the mind's eye. They provide more opportunity for the story-based value judgments we apply to any information we receive.

As much as stories should ring true to us, they should also absorb us to be better remembered. We paint deeper and more memorable mental images when information is delivered as narrative. Journalists, teachers and trial attorneys are all practiced storytellers, delivering clear and often dry facts with the narrative arc of a thriller to better hold audience attention. "Human minds yield helplessly to the suction of story," writes Gottschall (2012). "No matter how hard we concentrate, no matter how hard we dig in our heels, we can't resist the gravity of alternative worlds." (p. 3)

8.2 Transmedia Storytelling

Though the ideas behind it have been described with other terms, Jenkins (2003, 2006) popularized the term *transmedia* storytelling and has identified its structure as used in entertainment media. He explained in his book *Convergence Culture* (2006):

> A transmedia story unfolds across multiple media platforms, with each new text making a distinctive and valuable contribution to the whole. In the ideal form of transmedia storytelling, each medium does what it does best—so that a story might be introduced in a film, expanded through television, novels, and comics; its world might be explored through game play or experienced as an amusement park attraction. Each franchise entry needs to be self-contained so you don't need to have seen the film to enjoy the game, and vice versa. (pp. 95–96)

In naming the technique, Jenkins identified its type species as *The Matrix* film franchise, in which the dystopian story unfolded via the silver screen, a series of animated shorts, games, comics, fan fiction, toys, and other media. Though each piece was a self-contained story, the whole of the franchise created a more complete picture of a world created by the authors than any one piece did alone. The structure of the story encouraged personal investigation and satisfied a common human impulse to discover for oneself.

Through a series of blog posts, Jenkins (2009a, b) further defined the technique by identifying "seven principles of transmedia storytelling". They include:

- *Spreadability vs. Drillability:* Good stories spread from one person to the next through sharing and interaction. Yet they can also inspire engaged audiences to drill ever deeper into the meaning, background and contexts of that story.
- *Continuity vs. Multiplicity:* Across diverse media a series of stories should maintain coherence. However the opposing approach of telling the same story in multiple, even opposing, ways can make that story rich and interesting.
- *Immersion vs. Extractability:* A reader enters into the world of the story, if even briefly, suspending disbelief and forgetting their real-world circumstances. However, a transmedia story may not only provide escape but inspire the audience to carry story elements into their daily lives.
- *Worldbuilding:* Each element of a transmedia implementation contributes to describing a story world where multiple characters follow multiple storylines. This creates in the mind's eye of the audience a more complex space for the stories to happen.
- *Seriality:* Stories that unfold in segments have held audience attention since before Dickens. In a transmedia implementation those segments may come not only through one medium, but several.
- *Subjectivity:* The multiple characters within a story would never see the same things in the same way, and their varying stories add new dimensions.
- *Performance:* The story encourages action from the audience, whether that may be in changing behavior or inspiring reenactment of the story itself.

These principles are methods of engagement for a public and would be used to inspire more than passive interaction with a story. Through an intriguing and complex story world, a public would be immersed deeply and inspired to share interconnected and serialized stories told from multiple points of view. Individuals might investigate further by drilling ever deeper into story contexts. They may extract physical and emotional elements for their own lives or choose to perform the stories themselves.

As foreign as many of those goals may seem to the fact-based world of Earth scientists, they are familiar to the world of educators and social scientists, such as communication scholars. For example, social processes of emulation and role-playing (Bandura 1977) as well as investigation and discussion (Tan et al. 2006) are long-understood processes of learning. And education is a primary goal of science communicators.

8.3 A Story World

A transmedia project explores a space that contains multiple characters who can each tell multiple stories. It's a space around which you can draw a border like the illusory world of *The Matrix*, the mysterious island of *Lost*, or that "galaxy far, far away". Jenkins (2006) recalled hearing the explanation of this evolution from an unnamed Hollywood screenwriter:

> When I first started, you would pitch a story because without a good story, you didn't really have a film. Later, once sequels started to take off, you pitched a character because a good character could support multiple stories. And now, you pitch a world because a world can support multiple characters and multiple stories across multiple media. (p. 114)

Ryan (2014) notes that "every story has its own storyworld (except in transmedial projects, where the representation of a world is distributed among many different texts of different media)" (p. 58). A storyworld requires narrative content.

Conceiving a storyworld is as simple as drawing a border. In science communication, a story world could be a physical space like a lab or university department, a social space like a community of practice, or an ongoing research space like climate change. Each of these spaces contains multiple interesting characters, and those characters (human or not) can tell multiple interesting stories. These stories can all stand on their own as discrete works across varying media, but taken as a whole they flesh out a world that is too large, nuanced, or complex for one story. Once engaged with any one story, the public can explore the story world and activate their personal investigatory impulse.

8.4 Understanding Media

But what of the second syllable of the keyword *transmedia*? Media is an elusive term containing many definitions under its umbrella. Meyrowitz (1993) includes media as either a language or a conduit in his analysis (p. 38). Ryan (2006), in her quest to define a *transmedial* narratology for the digital age, classifies media as semiotic phenomena, technologies, and cultural practices (pp. 16–25).

In American vernacular use, the word *media* can be understood in at least four different ways, thus encompassing a hierarchy of ideas that may be conflated or contextually misinterpreted. The first idea the word contains is media as a sociopolitical actor. This is *the media* often seen as a truth-spinning influence on public discourse or the *fourth estate* as understood by members of the press. A second idea is media as family, such as art, advertising, news, music, literature, and others. However, the two other ideas of media that are critical to transmedia storytelling are *form* and *channel*.

Media form is the language of media used in telling a story, from text to audio, video, cinema, photographs, illustration, and games. Media form is a structure that both Ryan (2006, pp. 16–25) and McLuhan (McLuhan and Zingrone 1995, pp. 178–185) describe as influencing our perceptions and understanding of story. But these forms can be delivered across many different channels. Where media form is the language used in the story, media channel is a connection point with an audience. The form of text, for example, can find its audience through channels such as books, newspapers, magazines, the Internet, film, television, graffiti, and even skywriting.

8.5 Distinguishing Media Forms

The interconnected stories from a storyworld take advantage of the different forms media can take. These 'languages' tell stories in unique ways. Stories should use the media form that best fits the way an individual story in our world should be told. Use of the best media form is also a critical method in reaching particular segments of the public in a manner that appeals to their members and fits circumstances in which they will find the story. Nearly any media form can tell a good factual story if we use our usual forethought and ethical rigor.

Text, the most venerable of media forms, is particularly good at fleshing out contexts, examining the invisible, and making connections between subject matter where those connections are otherwise difficult to see. Text does the intellectual heavy lifting, but it may or may not have the highest appeal to the audience we need to reach.

Audio is also a verbal medium and reasonably well suited to some of the work above, but it usually lacks the luxury of length. Our attention spans with audio media may be shorter than with text as it must be heard in real time rather than read at a faster speed. Stand-alone audio is notable for its ability to paint a mental image as we hear sparse details and must mentally construct the rest of a situation. This activity arguably deepens engagement by allowing us to virtually enter a scene ourselves. Here, character can be built simply through the voice of a subject and the emotion present in speaking.

Video tends to be a narrative form. Events unfold on screen in a predetermined order. A process is elaborated and illustrated within a classic narrative arc. Character is built through voice, the subtleties of motion in the human face, and other nonverbal cues. We are innately talented observers of expression, which fuels our judgment of individuals. Here, stories of process are well told. Interviews are also more nuanced when we hear a voice and see the slight and fleeting expressions in tandem. With video we have the opportunity for both reported story interviews as well as stories told purely in the words of the subject.

Still photographs, by contrast, show their strength in freezing fleeting moments. Once frozen, we are free to stare at them interminably. In still photographs, narrative can be implied within the frame by the actions and emotion shown, or constructed from an orderly presentation of discrete moments. The breaks between frames, like audio, allow us to mentally fill in the blanks in story or the lack of sound. A picture engages our imagination in ways video tends not to. In science communication, we may choose still photographs to convey the excitement of the moment of discovery or to capture the decisive moment in a fleeting process. We might also build ordered narratives that ask for more visual contemplation and a more lingering pace, where each step of a process is frozen for our persistent gaze.

Like a chameleon, *non-photographic illustration* can change style with the channel presenting it. This most ancient of communication forms holds promise for its ability to visually represent what is inaccessible to the camera. It has traditionally been used to graphically visualize data and its interrelations or interactions. *Graphic nonfiction* (comic-like) forms have proven successful in reaching subjects that are unreachable to cameras and doing so in a language familiar to particular segments of the public. For example, journalist-artist Joe Sacco published graphic nonfiction books on Balkan genocide and past Palestinian conflicts all based on eyewitness accounts and interviews (Sacco 2000, 2001). Using similar techniques, Neufeld (2007, 2009) produced a book on surviving Hurricane Katrina through the stories of a handful of characters.

Online media, at once distinct from and overlapping with other forms, take center stage in transmedia storytelling. Distinguishing factors online include immediacy and interactivity. Interaction is a key to transmedia storytelling. Our publics gain a rightful sense of ownership in a story when they contribute to it meaningfully. What is important to a human research subject or a reader may complement the work of researchers. Allowing voices from outside can, when done well, bring more complexity and nuance to a story as well as add balance and needed transparency to the process of reporting. Interactivity is also frequently used along with the visualization of data discussed above. The ability to explore statistical information by drilling into, rearranging, or manipulating those relationships engages our mind on both visual and structural levels.

Interactivity is not exclusive to digital spaces. Interpersonal communication such as *lectures* or *live forums* by scientists are an old media form. To the public, a lecture holds the promise of personal insight not offered in other media. Lectures and forums are also communal events, where the public participates in a shared moment of engagement in a distraction-free setting with words spoken by the lecturer or forum participants in a singular way. The experience is unique to the crowd in ways that recorded media cannot be.

The immersion of the public is a long-sought state in any media. Like Hollywood producers, we hope our publics will lose themselves in our stories, if only momentarily. Immersion also comes from experiencing the story personally, and interactive physical displays or virtual reality systems can allow the public to get its fingers into our scientific Play-Doh®. Two immersive documentary projects created by USC researchers Nonny de la Peña and Peggy Weil illustrate this possibility. In one, participants virtually experience interrogation stress positions (de la Peña et al. 2010), and in another people literally participate in the shock of seeing someone slip into a diabetic coma in front of them as they wait in a virtual food bank line (personal communication, April 7, 2011).

Games are also immersive as they engage our sense of agency and place us in an active role in the story itself. Our avatars become participants in a virtual representation of a story and can determine that story's outcome. Critical to the sciences, games are particularly good at illustrating systems. Players personally experience how all the moving parts of a story interact to generate an outcome. Examples include addictive games EteRNA and Foldit in which players design RNA molecules or fold proteins in an act contributing data to the collective knowledge of these complex structures. Through the process of creation, the players experience the systems in which the elements of these biological building blocks interact ("Games for Science" 2013; Khatib et al. 2011; Markoff 2011).

Last on this list are collected *story artifacts*, though the end of this list is not the end of media form possibilities. Artifacts provide a physical and personal connection to the story. Seeing the material, the data, or the equipment used in the process of scientific study creates a personal connection for the public and a singular experience of the story impossible through recorded media. Any visitor to the Smithsonian Institution can attest to the unique experience of seeing the instruments of exploration first hand. These items illustrate what Benjamin (1968) described as the "aura of the work of art" present only in the original and not in the reproduction (p. 221).

8.6 Choosing Media Channels

If each story has an appropriate media form, then each audience has its most preferred media channels. The word *audience* is a bit fraught for its implication of passive reception of one-to-many media. We proceed here with the understanding that an audience in the digital age is an active participant in conversation with the producers of media. The audience should be as intentionally chosen as any other conversation partner, and learning about your intended audience via audience analysis research becomes an essential first step in communication. In a multimedia age media forms can be delivered or reproduced in a single digital channel like the Web or a mobile device. But websites or mobile apps, despite being multimedia spaces, are only single connection points with an audience. There is usually only one person in front of all the media forms, and much of the potential reach is wasted if that is the only channel used. In transmedia storytelling the media channel chosen provides access to a different key audience and a different possible entry point for them into the story world. Well-structured media channels can feed into and off of each other, sending an engaged reader from one story to the next across digital and analog spaces. Where we once worked to put our stories into mass media for the widest possible audience, now we can target the publics that we would like to engage. The question we can now ask is, "What is the right public to reach with this story?" Rather than wide nets that fish in vast seas, sometimes we should be dropping a few well-placed lines with good bait.

If story content and media form are our bait, then media channel is the fishing line. Those lines may include newspapers, magazines, radio, television (both broadcast and cable), books, and DVDs, as well as public lecture series, game systems or game-oriented websites, graphic nonfiction magazines and books, and museum displays. Channels may include the more experimental such as public projections, pamphlets, buttons, billboards, or any other medium in which a story may be told. Social media is a powerful tool for stories to spread as fans share them on their feeds, but these channels have been used to tell the stories too. Each of these diverse channels engages with a subset of the public at large. Though virtually any demographic can be reached through nearly any media channel, certain demographic groups can be found more easily in certain places.

8.7 Internet Spaces

The Internet Age is one of comprehensive change to the mediascape. The Internet itself has become a primary point of engagement, but it has also changed analog media and the way we interact with them. But what is the Internet? Is it a media form? A media channel? We argue that it is both and it is neither. The Internet, the Worldwide Web or any classification of online space is a meta channel that carries not only all the media forms described above, but meta forms as well.

The Internet is a bundle. Within that bundle are multiple media channels, each with a particular audience. Media channel is defined above not by the mechanics of delivery, but by the audience on the receiving end of it. Within the Internet bundle are countless individual channels, each with a particular audience on the other end. Each Website or each mobile app has a particular target audience. Since we seek to target our stories we must be specific about what online spaces are used.

The Web has also popularized *multimedia* (arguably more among media producers than media consumers). This multimodal meta form can combine text, audio, video, infographics, and interaction into a single stream of information. Each of those individual forms engages the senses in its individual way, and the combination is additive. "The hybrid or the meeting of two media is a moment of truth and revelation from which new form is born," McLuhan (McLuhan and Zingrone 1995) noted. "The moment of the meeting of media is a moment of freedom and release from the ordinary trance and numbness imposed by them on our senses" (p. 177). Despite the additive comprehension afforded by multimedia, it may not be as new as it seems. In its common form, Web multimedia is simply the form of video (or cinema) by another name. It is a combination of images, sound and text that had reached full development by 1929. The multimedia meta form may not reach maturity until the newer affordance of interactivity becomes integral to it.

The ever-expanding array of media forms and communication channels available provides diverse possibilities for arranging a world of stories. We can tell them one at a time, in serial, or all at once to form a complex network of information. By choosing the right form for each story we communicate more efficiently and, through the right channels, we reach particular publics with the information they want or need. The Supercomputing Center in Wyoming demonstrates these principles.

8.8 Transmedia Storytelling at the NCAR-Wyoming Supercomputing Center

The National Center for Atmospheric Research (NCAR) is a federally-funded research and development center devoted to service, research, and education in the atmospheric and related sciences. Its mission is to understand the behavior of the atmosphere and related physical, biological, and social systems; to serve the broader scientific community; and to foster transfer of knowledge and technology for the betterment of life on Earth. NCAR's primary funding comes from the National Science Foundation, with significant additional support provided by other U.S. government agencies, other national governments, and the private sector.

NCAR recently inaugurated the new NCAR-Wyoming Supercomputing Center (NWSC) and incorporated a public visitor center for educational and outreach purposes. The visitor center is intended as a self-guided activity and designed to reach a broad range of ages and educational backgrounds. At the same time, it is part of NCAR's broader outreach to dispersed audiences, conveying parts of a large, complex story about supercomputing, science, and society.

In developing a new visitor center for the National Center for Atmospheric Research (NCAR)-Wyoming Supercomputing Center (NWSC), our goal was to provide an educational experience that engaged the public in topics that include supercomputing, scientific research, atmospheric and related geoscience, and careers in science and science support. We also wanted to show how all of these are relevant to everyday lives. Because the stories are complex and varied, our approach was to use multiple media forms and channels to connect not only with visitors to the center, but also with audiences who might never visit the physical space due to geographic or other constraints.

The dispersed audiences vary in age, interests, education level, social engagement, political views, and attitude about the information we present. Therefore, it is important to understand how to reach these audiences in the most effective manner and how to craft the message in a way that is relevant to each media channel and its audience.

At the NWSC, we engage visitors through text, still images, videos, personal stories, teacher-led activities, guided tours, games, and interactive exercises and channels for public feedback. For example, to teach visitors about the critical need for supercomputing to solve complex problems in science, we have an interactive game that shows how parallel processing works, where the user can set the number of people mowing a field and see how more people working on it decreases the time it takes to complete the task. To give a sense of how fast the machine can run its calculations, we have a hand-swipe sensor, where visitors can swipe their hand as fast as possible and see the number of calculations the supercomputer completed in the fraction of a second of the swipe. A video that explores the inside of the supercomputer helps explain how the machine itself works. An interactive hand-crank allows visitors to understand the relationship between computing and power, and how much power it takes to run machines tackling the most complex scientific questions of our time.

The NWSC benefits from joining an already well-established educational and communications outreach program, not only from NCAR and its managing entity, the University Corporation for Atmospheric Research (UCAR), but also from partner institutions that were instrumental in making the NWSC a reality, and continue their affiliation with the center. Among them are the University of Wyoming and Cheyenne, Wyoming-based economic development, and industry groups. While the NWSC is part of the NCAR/UCAR family, it is also a new type of collaborative endeavor, in a separate location, integrating with a new community.

An introductory video about the facility, the supercomputer, the science, and how these matter for society is played at the NWSC, but it is also echoed on the NCAR YouTube channel (http://www.youtube.com/user/ncarucar) along with a dozen other video "shorts" about different topics like wildfires, climate, extreme weather, the fleet of aircraft that collect atmospheric data, human health, and energy. These stories each have their own characters (the researchers, pilots, etc.), and their own plots. But they also relate to the larger stories about scientific research and the even larger story of how science permeates every aspect of how we understand our world. Visitors to the NWSC can enjoy all these stories on-site, but they can also revisit them and spread them to additional audiences (friends, students, social groups) remotely.

We also developed an animated short about "Dr. Tornado" (http://www.youtube.com/watch?feature=player_embedded&v=N9eNbUgiQz4), which tells the story of how science is practiced in the age of supercomputers. This piece reaches our YouTube audience, but is also embedded in a number of websites and was presented via social media outlets (Facebook, Twitter) to additional audiences. We regularly use social media to interact with our audiences about new developments, news stories, events, and educational or career opportunities, in addition to more "traditional" channels like newspapers or career portals.

In designing the NWSC visitor center, we wanted to build on all the channels and forms that were already being used by our partner institutions, while developing a rich experience for the on-site visitor. It was important to create a means for visitors to take the information with them and be able to continue their exploration after their visit to the center. Each story featured in the NWSC displays has QR codes that link to additional resources, so visitors with smartphones can deepen their knowledge either on-site or at another time.

These outreach efforts join the ranks of NCAR/UCAR's established public outreach and education programs, which include classroom activities, lectures, workshops, science fairs, interactions with print and broadcast media, podcasts, quarterly magazine, and community programs.

8.9 Conclusion

What we're finding in this endeavor is that there is no "The End" in transmedia storytelling. Rather, the story becomes organic by virtue of audience interaction. Whether it be a demand for additional communication forms or channels, engagement with previously unexpected audiences, or the discovery that no hand-crank can be built tough enough to withstand the onslaught of an enthusiastic middle school class, engaging the public requires a willingness to revisit, reorganize, expand, and redirect the story, and an understanding that it will evolve in fascinating and often unexpected ways.

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Chapter 9
Experience Our Planet—Interpreting Earth Sciences in a Museum Environment

Simon Schneider and Gilla Simon

> *"Museums provide opportunities for the appreciation, understanding and management of the natural and cultural heritage" … "Museums have an important duty to develop their educational role and attract wider audiences from the community, locality, or group they serve. Interaction with the constituent community and promotion of their heritage is an integral part of the educational role of the museum."—§ 4, International Council of Museums (2004) code of ethics for museums*

You could say Earth makes itself at home in any museum. Whether it is an art gallery, a technology exhibition, or a national park visitor center—Earth science interpretation not only is possible but sometimes even more successful in unexpected locations.

When transplanting Earth science interpretation from the usual places, planting a few seeds may be all it takes, a concept eloquently stated as early as the nineteenth century by French author and Nobel-Laureate Anatole France:

> Do not try to satisfy your vanity by teaching a great many things. Awaken peoples' curiosity! It's enough to open minds, do not overload them. Put there just a spark. If there is some good inflammable stuff, it will catch fire. (as cited in Ward and Wilkinson 2006, p. 24)

France spoke about *inflammable stuff* meaning interest, curiosity, and the need to know.

In today's Information Age (Messenger 1982), audiences crave basic scientific knowledge to be able to form opinions on their own. Talking about the strong

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interconnectedness and interdependence between science and life will foster the understanding of basic as well as complex processes in our socio-economic setting. Simply put, science communication is fundamental for modern societies. Anatole France already knew about this, and he supported science communication wherever possible.

There are two sides to Earth science communication in museum environments. There is the slow and shy approach from scientists toward museums, and there are the new demands of the Information Age on museums to develop into multitasking, educational, and entertaining facilitators of knowledge. Some argue "that museums need to move from being suppliers of information to providing usable knowledge together with the tools for visitors to explore their own ideas and reach their own conclusions" (Bradburne 1998). But museums often have to climb monstrous hurdles even to start networking with scientific organizations and institutions. There is still some skepticism toward providing "hard scientific facts" in a public setting, where the strong and robust scientific language will be translated into everyday language (Hilgartner 1990).

This chapter aims at both sides as it overviews first the Earth science museum today, next audience-centered communication, and finally best practices in museums around the world. Before concluding, we take a closer look at the interpretive opportunities of crystals and stones. Throughout the chapter, we share insights for conducting interpretive programs in museums and national parks and encourage scientists to participate in the face-to-face interpretive opportunities provided by such venues.

9.1 The State of the Earth Science Museum

Museums address various topics, but only a handful of major Earth Science Museums are established throughout the world. There are a lot of regional museums, sometimes as small as a single room or a shed somewhere in the wild, interpreting geological features like outstanding rock formations, paleontological discoveries, or breathtaking lookouts. But these locations are limited, both in the capacity of issues within the exhibition and in financial resources for additional programming. The Earth sciences are the focus of mining and mineral exhibitions and collections, but they are oftentimes strongly merged with industry interests or overlain by the historic component of mining history in the region. Other places to find Earth science information are mid-sized museums at universities, but a large-scale museum about the System Earth is hard to find.

Regardless, there are numerous ways to interpret Earth sciences in a museum environment. Exhibition areas about plate tectonics, volcanoes, or natural hazards are common in natural and natural history museums. Occasionally even mineralogical features such as common rock types and natural resources are chapters within these museums. Sometimes rocks, ores, and raw materials are also picked out as a central theme.

Over the last couple of years, museums have been transforming passive display presentations into multi-media, hands-on experiences in large part because such exhibits increase the quality of the visitor experience (for example Morris Hargreaves McIntyre 2008). Since learning is voluntary in a museum setting, appeal determines whether or not visitors will interact with an exhibit (Hudec 2004). Consequently, hands-on represents a critical tool as an attraction for visitors. Similarly, research on the use of computers in art galleries suggests that “when thoughtfully designed and carefully positioned, interactive systems can actually complement and increase the enjoyment of the exhibits by acting as supplements and enhancements, rather than replacing them” (Allison and Gwaltney 1991).

Museum priorities have changed over time. Early on, museums were established on the basis of private collections. Regardless of whether they are a cabinet of curiosities or a detailed presentation of regional life and evolution—museums all over the world exist because someone somewhere started a collection. Hence, our Earth is collected in drawers and closets, in boxes and phials. The purpose of today’s museums is not only to collect, preserve, and conserve the items but also to undertake research with the collections. The results of this scientific work should be presented in exhibitions and imparted for individual and guided visitors. In fact, most collections have a huge number of specimens representing the bio- and geo-diversity of our planet.

Accordingly, museum collections are a great resource for Earth science communication. While talking about geological processes, about the evolution of life or the use of crystals in our everyday life, the presentation will be more exciting if hands-on specimens like rocks, fossils, and minerals are used. Such specimens not only liven up an apparently dry topic, but they also promote the interactivity between speaker and listener (Fig. 9.1).

What science has to learn from museum environments is that museums are more than just showcases for artifacts, exhibits, and pictures. Museums maintain a complex and multifarious infrastructure, not only to support the presentation but also to develop new and innovative approaches in communicating content, to develop and conduct innovative and creative programs, and to preserve collections and prepare specimens. The communicative know-how at museums is highly specialized to present complex issues. Educationalists who bring curriculum expertise to museums, translate scientific vocabulary into a suitable language for different audiences. They are trained in developing educational programs like guided tours, workshops, excursions, children’s birthday parties, family weekends, book signings, talks, and lectures as well as other special events such as International Museum Days or Long Night of Museums.

Finally, scientists should bear in mind that museums offer a highly interested and motivated audience. Most visitors are looking not only for entertainment but also for facts and ideas to become inspired and informed. Museum visitors are “uniformly interested in the beginning of the universe, the Big Bang, and how planets are formed. They knew little about these topics, but desire an interactive experience” (Shoup and Associates 1995). If this experience is coupled with the most recent scientific work, with stories that relate the research to the visitor’s daily life, and with new—maybe unsuspected—information, the visitors will leave the museum satisfied and will likely come back soon to learn more.

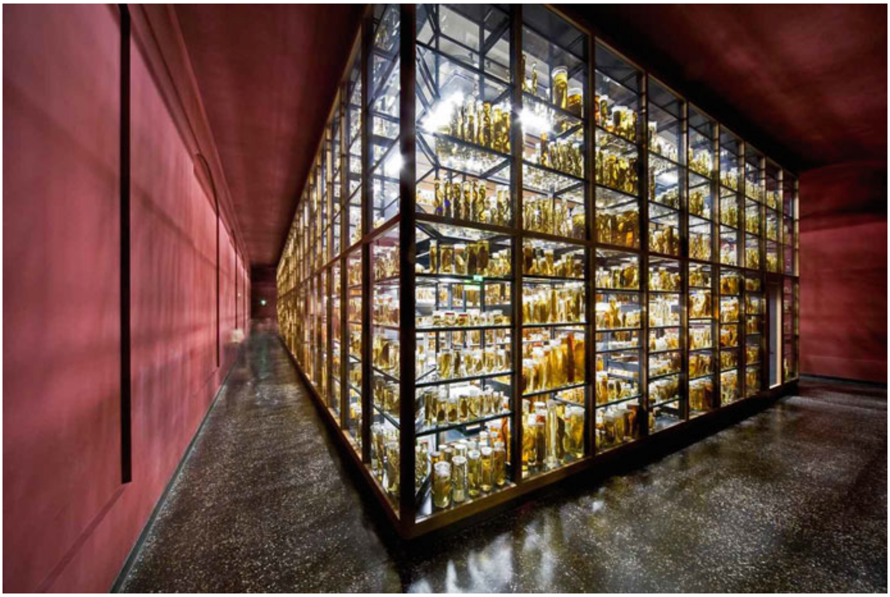

Fig. 9.1 Collection on display. At the Naturkundemuseum Berlin, visitors get a feeling for what is going on behind the scene of Germany's largest museum for naturals history. The glass cube containing large parts of the ichthyologic collection, is only accessible by the public on the outside. Nevertheless, the collection presented is still in use for scientific research (Picture by Naturkundemuseum Berlin)

9.2 Audience-Centered Communication

Public Understanding of Science and Humanities (PUSH) has become the focus of controversial discussion within both protagonist camps: scientists are no longer willing to "downsize" and translate their research without proper support by agencies and policy, while communication research has shown that science communication by itself is not the suitable tool for building the targeted "understanding of science" (for example Renn 1986; Schiele et al. 2012). Acceptance and support of the scientific process are not dependent on dissemination of factual information alone. To generate and intensify the acceptance and the appreciation of research, the public has to be involved. Communicators have to relate scientific research to something within the personality or experience of the visitor, consequently, scientists should be aware of interpretive opportunities.

9.3 Interpretive Opportunities

American journalist and author Freeman Tilden (1977) defined the function of interpretation as "an educational activity, which aims to reveal meaning and relationship through the use of original objects, by firsthand experience, and by illustrative

Fig. 9.2 The interactive and multi-media display on Climate Change at the Miami Science Museum. This exhibit encourages visitors to make discoveries about Climate Change on their own and relates the displayed science to the daily experience by using not only scientific results but also pictures and animations (Picture by Miami Science Museum, http://www.miamisci.org/)

media, rather than simply to communicate factual information" (p. 8). He developed this definition while looking at museums and national parks in the United States in the early 1950s with a strong focus on natural and cultural heritage interpretation. Today, his idea of interpretation is still true and should be transferred to science interpretation as well. The key message is that communication about scientific topics should always be related to the visitors' own experiences in daily life and to the environment in which the audience lives. Revealing these relations creates meaning. Similarly, firsthand experiences will make the interpretive program memorable. And finally, original objects combined with meaningful and memorable interpretation will create a moving experience. This concept should be a guideline for the development of all science communication efforts.

Wells et al. (2013) quoted Sir Ken Robinson that "rather than anesthetizing learners using the traditional factory model [of education] we should be waking them up by stimulating their imaginations and creativity" (p. 17). Ergo, taking science into museums should not have strict learning as a goal; instead, it should focus on provoking critical thinking and curiosity (Fig. 9.2).

An important principle within developing programs for science communication in museums is the so-called interpretive equation (National Park Service 1999, 2000; Larsen n.d., 1998):

$$(KR + KA)\,AT = IO$$

This equation summarizes a scheme to obtain the key factors for successful interpretation. Within the equation, KR represents the interpreter's "knowledge of the resource," KA represents the interpreter's "knowledge of the audience," AT represents the interpreter's use of an "appropriate technique," and IO represents the production of an "interpretive opportunity" for visitors.

The higher the interpretive opportunity, the more successful the interpretive program has been. Notwithstanding, "the visitor is sovereign and will ultimately decide on the meanings, value, and preservation of the resource" (Larsen n.d.). Chen (2000) observed that:

> "..in general, research studies are not well-distributed among the four areas represented by the interpretive equation: knowledge of the resource, knowledge of the audience, appropriate technique and interpretive opportunity." Chen also criticizes, that "appropriate techniques and interpretive *outcomes* (not equal to the IO in the equation) have been the focus of most interpretive research, while knowledge of the resource and knowledge of the audience have not been well explored in research studies." (pp. 7–8)

Thus, communication scholars can inform this vacuum particularly in relation to audience, media, rhetorical strategy, mediated communication, and countless other aspects of human interaction. Likewise, an expansive body of knowledge from the field of education can add invaluable insights via learning theories, strategies, and assessment methods.

To give an example of how the interpretive equation works, take Earth science communication in art galleries. A venue devoted to fine arts is not the place one would expect Earth science interpretation. Even so, there are plenty of opportunities to talk about natural hazards, climate change issues, or anthropo-geographic themes. If the communicator is well prepared, the KR factor is maximized. Visitor studies are well established in art galleries, so KA is equally maximized. By choosing the best interpretive technique, such as science happenings, provocative performances, or simply guided tours (if the audience is receptive to this kind of interpretation), the Interpretive Opportunity will become optimized (Fig. 9.3).

9.4 Communication Matters

To start the conversation about Earth sciences and to keep it going, museum professionals need to be cognizant of many factors, including the medium and the message. Scientists and others who start an exhibition project often underestimate the impact of accompanying text, for instance. It is easy to damage the good impression of a well-made exhibition by using too much text, the wrong style and language, or scientific terms and tone. While the question raised by Eric Leyland "Do Visitors

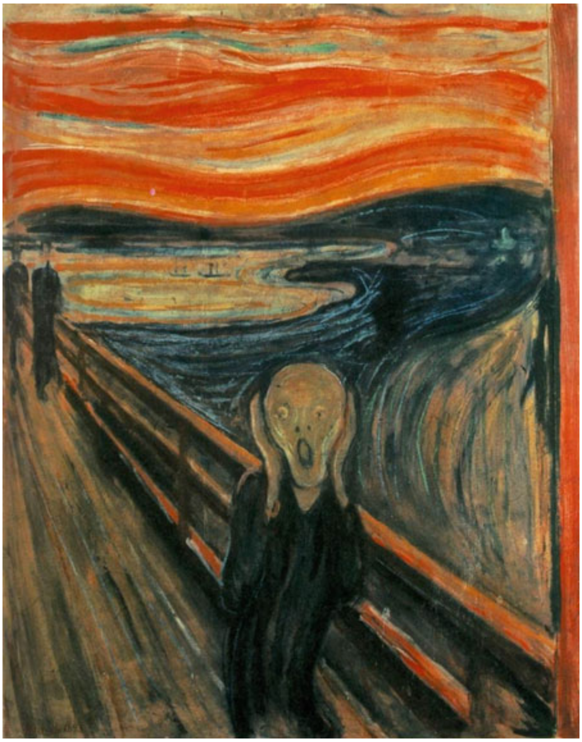

Fig. 9.3 Interpreting volcanic eruption in front of Edward Munch's famous painting "The Scream" presents a great Interpretive Opportunity. It is widely believed, that the painting Skrik (The Scream) by Edvard Munch represents the real-life red sky that had been all over Europe and Asia and some parts of the United States in 1883. The uniquely colored sky that lasted for 3 months was the result of volcanic ash spreading from the powerful eruption of our Krakatau in 1883

Still Read Interpretive Text Panels?" seems to address a pertinent question among museum professionals and interpreters, only a limited number of studies have been conducted about the reception of text by visitors. Leyland summarized a LinkedIn discussion on the issue by stating, "the consensus seems to be that *yes* visitors still do read the exhibit text panels *but* there appears to be questions over how many, and how much of the text gets read." Later in the discussion, Leyland adds, that "Studies have identified that some people are *divers*, who stand and read every word. Others are *swimmers*, which means they read part way. While the rest are *skimmers*, who read only the titles" (Leyland 2011).

Who is doing the reading matters. Timeless principles of communication apply in the museum setting such as being audience-centered. Ferguson (1995) observed the purpose of the text, who will read it, and where and how the text will be used should be known by the exhibition team before writing even begins. Moreover, when writers answer the five Ws (who, what, when, where, why), they are using journalism fundamentals. Kentley and Negus (1989) mentioned, "The general aim of the object panels is to explain what the objects on display are and their significance, by giving a brief description of the who, what, when, where".

It becomes obvious, that writing exhibition text (like all communication) is an art and a science of its own. "Too often writing is seen as unimportant, something done in a spare half-hour. Writing which commands attention and is memorable is hard work" (Carter 1993). Tip-sheets proffer guidelines about how to write effective text for exhibitions (see for example the London Metropolitan University tip sheet n.d.). The most prominent recommendations suggest:

- addressing the reader in first person writing,
- using active rather than passive wordage,
- asking questions to get the reader involved and engaged, and
- writing in short sentences and paragraphs.

A summary on research related to the effectiveness and reception of exhibition text is given by Bitgood (2000).

Besides exhibitions and collections themselves, museums offer an awesome setting with a lot of ambience for public talks, guided tours and various other educational programs.

Public talks, for example, offer opportunities not only to give away information but also to create interaction with the audience. By giving keynote or stimulus lectures, scientists are able to “spark” or initiate curiosity. In addition, follow-up events such as open forum discussions and informal tours will help to start a dialogue. This will get people involved in the scientific process and will help science to become human, tearing down barriers between the “lay audience” and the scientists.

One effect of public talks is to transfer scientific issues from the political and scientific agenda to the personal agenda. Communication scientists call this effect agenda setting (McCombs and Shaw 1972). Agenda setting is widely analyzed with regard to the interdependence of media agenda and personal agenda or in terms of an inter-media agenda setting. Meanwhile, the effects of science communication on the public agenda are not yet in the focus of communication sciences. But the direct interaction between scientists and the public will doubtless increase the knowledge, acceptance, and appreciation of science.

9.5 Best Practices in the Earth Science Museum

Boundless possibilities exist within the Earth science museum. From new ways of tapping into mobile technologies and movable feats made possible by innovative partnerships to up-close-and-personal experiences with experts—the sky (and the Earth) is the limit.

9.5.1 Audio Guides and Apps Tap New Technologies

Museums use many communication and educational strategies, including the latest technologies. Sometimes misjudged as a kind of gimmick, technologies for non-personal audio-based interpretation can substantially contribute to the success of exhibitions. Various kinds of audio guides with players that can be borrowed in the museum itself are ready to be implemented in an exhibition, even with a limited budget on the technology side. But creating a sustainable input to an audio guide system is hard work and, if done in the best available quality, expensive.

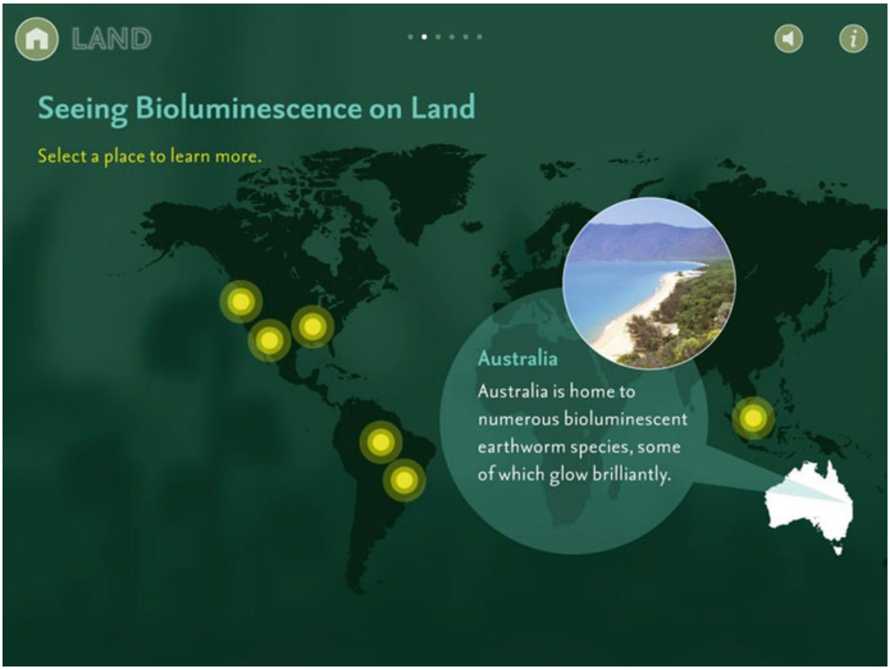

Fig. 9.4 Screenshot of the price-winning exhibition app about Bioluminescence, used by the American Museum of Natural History

Composing exhibit and artifact descriptions for any media requires a skilled writer, but writing for audio is distinct. In addition to writing for the ear rather than the eye, you also have to think about "the voice". The best text is wasted if the narrator is not a professional and if the voice is not suitable for topic or audience. After all, audio guides offer a wonderful opportunity to provoke emotions. Imagine an exhibition about a volcanic eruption with visitors simultaneously listening to a fictitious discussion of decision makers on how to deal with the volcanic threat. Combining sensory stimuli can be moving and memorable.

While audio guides are expensive, the newest trend in presenting content via acoustic technologies is the use of apps for mobile phones and portable electronic devices. Apps are able not only to present spoken information on exhibits and artifacts, but also to give background information and additional visual content. This technology has become one of the most discussed interpretive technologies among museum professionals in the last couple of years. While apps are still not common to most museum visitors, the next generation of visitors will be native to them. The benefits are obvious: visitors can decide which kind of information they want to use, they do not have to borrow an instrument at the museum, and applications are accessible to handicapped visitors as well. From the perspective of museum professionals, another reason springs to mind: applications are easy to maintain. New scientific findings or most recent discussions on the topic presented can be added to the system, while editing traditional audio guide content is time-consuming and expensive (Fig. 9.4).

9.6 Traveling Exhibitions Build Capacity

Another successful way to communicate scientific issues is the use of traveling or special exhibitions. By using special or temporary exhibitions, the opportunity arises to present themes like sustainability or energy efficiency from a new and most recent perspective.

Traveling exhibitions represent great tools for research organizations that do not have a museum. Research topics can be communicated to the public by creating exhibitions, which then will travel to several museums. This is an opportunity for science interpretation, because especially small museums often lack the capacity to develop new exhibits on their own. If scientific organizations and museums cooperate, then they can share collective resources such as materials, time, consulting with experts on particular themes of interest (e.g. family learning or accessibility), as well as time with evaluators. Within a strong network, each partner can also use the others as peer reviewers. Feedback at network meetings will provide new perspectives on ideas and designs. By using their collective resources the cooperation partners will be able to build better exhibitions as a group than they could alone, as Carroll et al. (2005) conclude in an evaluation report on traveling exhibits at science museums.

Another important factor for traveling exhibitions to become successful communication tools is that, because of the typically limited number of staff, there are few scientists on the team. Consequently, the variety of themes and sciences represented within the staff is limited and a large number of disciplines will not be represented at all. To that end, there is both a need and an opportunity to develop the exhibit-building capacity of small museums by cooperating with research institutions and organizations. “A collaborative, therefore, is not only seen as a good way to build better exhibits, but is also seen as a good way to engage in a collective capacity-building endeavor” (Carroll et al. 2005).

9.7 Educationalists Add a Personal Touch

Nothing replaces face-to-face impact, and this is the power of those who lead educational programs within museums. Educationalists direct their participants with a red thread and focus attention on known and new facts, but also involve their audience by asking questions, passing around hands-on specimens, or making participants carry out a quick experiment. The most important aim of a guided tour is not to give a vast amount of information to the audience but to initiate enthusiasm so that the visit becomes a lasting experience. Perhaps this is why special events like International Museum Days or Long Nights of the Museums are so well received. Comparable with fairs, such events offer an ideal opportunity to interest new audiences in Earth sciences. Consider information points with video on a continual loop or a Wheel of Fortune ™ prize wheel where simple questions are asked (Fig. 9.5).

Fig. 9.5 A group of students of a primary school exploring our planet Earth. Note that the educationalist speaks into a microphone and the students listen over headsets. The advantage of such a guiding system is that the group is "led at the cord" and the educationalist can speak in a standard volume (Picture by Museum Mensch und Natur, Munich)

How do educationalists know where to begin? Again considering audience-centeredness, the duration and quantity of content should be oriented toward the age and educational level of the target group. Outlining a guide for school classes should bear curriculums in mind, considering not only repeating subjects but offering additional content as well. You might think about an experiment on convection when explaining the Earth as a zoned planet or have an artificial volcanic eruption while talking about magma, lava, and volcanoes—the latter being a popular subject for children's workshops and birthday parties (Fig. 9.6).

Another popular topic is stones, which can serve many purposes. A colorful heap of many different types of rocks, minerals, fossils, and precious stones makes a great attention-getter or focal point. At the beginning, the group has a try to sort the "chaos" of different objects. The participants themselves will notice that there are many different ways of solving this task. For example, one can organize by a type (mineral, rock, fossil), color, shape, size, and other possibilities. Ultimately, the guide should lead to the group to discussing how scientists differentiate since rock determination is a suitable subject for adults and children. When selecting rock samples, it is helpful to take regional aspects into account and to choose common rock types (e.g., pebbles, which usually comprise very different rock types). At children's programs a small collection (e.g., six samples) can be assembled, and a brief description (rock name, mineral content, rock type, origin, etc.) may be compiled. Even better? The rocks can be stored in individual seedling boxes to send home with each child.

Fig. 9.6 During a workshop these boys have poured their own volcano made of plaster. They now let it erupt with baking powder and red ink (Picture by Museum Mensch und Natur, Munich)

9.8 A Showcase Study of Crystals and Stones

It is easy to imagine how stones and crystals can help make science, in a word, *rock*. Earth sciences can benefit from the creative and strategic use of many channels to engage different audiences, so to fuel the brainstorming we will dig a bit deeper now with actual scenarios.

Crystals are recognized as treasures of nature: beautiful, colorful, and omnipresent in our everyday life. Usually, crystals are presented in showcases with a legend including the mineral name, mineral formula, and its place of discovery. In most cases they are systematically arranged by mineral. Such exhibitions can seem boring, especially for younger visitors. However, crystals can tell us something about properties (e.g. hardness, color) but also about their technical daily use.

So then, a different approach for presenting crystals may activate other senses. Why not smell or touch minerals? Crystals often have regular geometrical shapes which can be touched; for example feeling a cube of pyrite allows one to realize that it has faces, angles and edges. Also differences such as rough or smooth, hard or soft can be demonstrated. However, such an experience is even more intense if visitors at first cannot see the exhibit. A possibility is to “hide” the crystal in a box but allowing the visitor to open it by a drop side. This type of presentation that allows visitors to touch the crystal is particularly useful for individuals with visual impairments.

Fig. 9.7 A visitor studying a thin section through a special rock microscope, which is housed in a tube and inserted itself in a basalt column. On the screen information about rock name, rock type etc. and even about the research method is displayed. Furthermore, the visitor can get the story of the rock told by taking-off a headset (on the right side and therefore not visible) (Picture by Museum Mensch und Natur, Munich)

While rocks are highly esthetic objects by themselves, the visual appeal can be enhanced by providing a view at a thin section under crossed nicols. However, visitors are overtaxed using usual scientific polarization microscopes: they have difficulties by setting intraocular distance and focus. For that reason, it is wise to install special polarization microscopes in exhibitions. But there are rare easy-viewing microscopes on the market (e.g. “Wentzscope”). An alternative is to construct a special rock microscope itself. Source of light, optic, polarization filters, thin section and objective of the microscope may be housed in a tube, which is inserted itself in a boulder of the same rock type. The viewer will be able to look at the thin section through a magnifying glass and to rotate the sample by 360°. Such a construction does not allow manipulation of the experiment by visitors such as changing the magnification or taking a polarizing filter out of the optic system. The microscope experiment should be completed by a screen or text panel, giving information about the rock name, rock type, mineral content, place of discovery, and also about the research method itself. Such an exhibit is even more interesting for both children and adults if the rock is telling its story for example via an audio station or an interactive exhibit app (Fig. 9.7).

9.9 Conclusion

With so many possibilities for Earth science in virtually any type of museum, it is important to ask, how do museum visitors understand the universe? Schoemer (1999) has attempted to answer this question, and the results are important not only to museum staff but also to scientists who struggle with the way science is presented in exhibitions.

The concepts of size and time scales in Earth science, for example, are known as the two most misunderstood issues. Studies show both concepts are known. Nevertheless, most visitors not professionally or semi-professionally involved in the natural sciences are not able to correctly fit information and facts into these concepts. Geologists accept the geological time scale as an integral to their work. It is the central theme of geology, in fact. Allmon and Ross (2005) articulate the dialectic and thus the dilemma for museums:

> …understanding of geologic time is also essential for general science literacy. It is thus ironic that geologic time is among the areas of geology most poorly understood by the general public. This is particularly true in otherwise highly popular and successful museum exhibits" (p. 151).

Allmon and his colleagues think "Museum exhibits on geologic time should build on the strength of museums, which is objects and how they can be interpreted to yield insights about natural processes" (p. 151). We go a bit further.

We believe cooperation between museums and scientists can also substantially increase their impact in interpreting geological time scales by creating a memorable experience. Interpreting geological time underscores the disparity between what Earth scientists think is important about the subject and what non-scientists are willing to accept as important. Scientific controversy about where to put boundaries within the stratigraphic tables does not help to create acceptance and appreciation of geological concepts about time. What will arouse curiosity is the technology and methodology of geological dating. Museum professionals and Earth scientists would do well to remember the wise words of Anatole France (1860): "The whole art of teaching is only the art of awakening the natural curiosity of young minds for the purpose of satisfying it afterwards". (p. 198)

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Chapter 10
Impacts of Geospatial Information for Decision Making

Francoise Pearlman, Richard Bernknopf, Mary Ann Stewart, and Jay S. Pearlman

Geospatial information contributes to decisions by both societal decision-makers and individuals. Investments in geospatial data have become a part of the political and policy debates that are focused on reducing government spending, as well as increasing societal wellbeing. Although many examples in our everyday life come to mind, good benchmarks of the value of geospatial information are missing. Quantifying this value involves comparisons of the decisions that would have been made with and without the information, and what the consequences of those decisions would have been. The Value of Information (VOI) is linked to the outcome of choice in uncertain situations. Individuals may be willing to pay for improved information depending on how uncertain they are, what is at stake, and the degree to which the benefit exceeds the cost of the information (Macauley 2006). Problems with data access, content interpretation (due to obscure file formats, for example) or use of the data all reduce the information value. Systematic analysis of the benefits of geospatial information in decisions focuses on the quantitative demonstration of why and how scientific data such as earth observations have economic value. Case studies apply the science and technology of geospatial data to inform decisions concerning the costs and benefits of economic and resource development. Two cases studies are provided which show net economic value but different approaches

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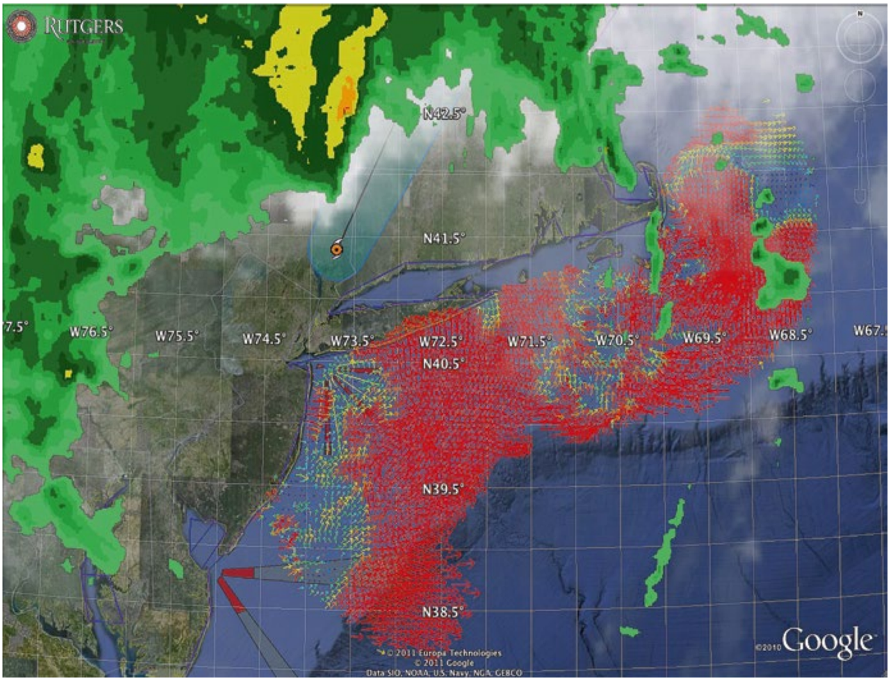

Fig. 10.1 Image of Hurricane Sandy as observed by the US Integrated Ocean Observing System

to assessing the VOI. Further steps in refining communication skills, providing a broad acceptance of approaches and a pool of experts to support community needs is envisioned in addressing paths forward.

The idea that information has socioeconomic value in both a statistical and a pragmatic sense dates back at least to the 1950s (personal communication, Macauley 2012). In recent years, interest in the socioeconomic value of information has taken center stage. Investments in geospatial data have become a part of the political and policy debates that are focused on reducing government spending, as well as increasing societal wellbeing. A recent example is that of the East coast storm Sandy. The information regarding Sandy's landfall (Spinrad 2012) (Fig. 10.1), and associated decision to close the New York subways, may have minimized damage to New York's infrastructure as well as saving many lives (personal communication, Spinrad 2012). Although many examples in our everyday life come to mind, good benchmarks of the value of geospatial information are missing (Macauley and Shih 2010). Thus there is a need and call for more case studies. These studies should cover a wide range of topics, methods of analysis, and places where they are undertaken. The case studies should be replicable and a compendium of them be assembled for distribution as guidelines and references for implementation in support of geospatial information initiatives (Pearlman and Bernknopf 2012).

The objective of analysis is to reduce the uncertainty in economic decisions and to attribute an economic value of the reduction in uncertainty due to the use of geospatial data in applications. Geospatial data and information is valuable when it allows individuals and firms to improve their decision-making. By making such adjustments, efficiency of resource use is improved, profits are increased, and consumer wellbeing is enhanced (Nelson et al. 2006). The approach is to follow accepted analytical principles of benefit – cost analysis (BCA). The first step is to establish the decision framework. It represents the *marketplace* for those who invest in information collection (supply) to better understand the needs of those who use the information (demand). Decision makers face the burden of justifying investment in geospatial data that, in many cases, requires the analysis of the economic benefits of that data.

Because *socioeconomic benefit* information is not normally traded in markets, quantifying its value involves comparisons of the decisions that would have been made with and without the information, and what the consequences of those decisions would have been. Quantifying the *gross* value of improved information means subtracting the expected value of actions without the benefit of the information from the value of actions with the information (Nelson et al. 2006). Quantifying the *net* value of new information entails subtracting the costs of providing the information from the gross value.[1] In this paper, after discussing the technical approaches, two case studies summarize applications of geospatial data that evaluated specific societal issues and problems that are based on BCA.

10.1 Socioeconomic Benefits of Earth Observation – A Short History

As indicated above, quantifying the socioeconomic impacts from improved environmental information has been under consideration for a number of years. *Environment* is used here as a term that broadly encompasses areas such as food, water, and energy security, or disaster relief (Group on Earth Observation n.d.) when addressing societal benefits. Impacts need to be addressed at multiple scales (i.e., local, regional, and global levels). Information includes that captured via remote and in-situ sensing, geographic information, and related systems (GIS), and spatial data infrastructures. The need for understanding environmental dynamics has become more urgent given the recognized issues of climate change, sustainable food sources, and increased need for energy (Borzachiello and Craglia 2011). Scientists are often being called upon to provide scientific information to support decision-makers. As recently as January 26, 2013, Bill Gates wrote about the importance of measurements in achieving the Millennium Development Goals (http://mdgs.un.org), and providing examples in public health (Gates 2013).

[1] This approach to valuing information has broad theoretical underpinnings in the literature on Bayesian decision making (Bradford and Kelejian 1977, 1978).

In order to make environmental information as useful as possible, it must be provided in a way that is societally relevant, targeted to the needs of the user, and understandable by the broadest constituency.

Drawing in social scientists, economists and the public health community, for example, to work with scientists and engineers is necessary for comprehensive and sustainable solutions to the grand challenges of humanity. The International Council for Science (ICSU), in a recent study, identifies these *grand challenges* for the global scientific community in moving toward sustainable solutions (ICSU 2010):

- Developing the observation systems needed to manage global and regional environmental change;
- Improving the usefulness of forecasts of future environmental conditions and their consequences for people;
- Recognizing key thresholds or non-linear changes to improve our ability to anticipate, recognize, avoid and adapt to abrupt global environmental change;
- Determining what institutional, economic, and behavioral responses can enable effective steps toward global sustainability; and
- Encouraging innovation (coupled with sound mechanisms for evaluation) in developing technological, policy, and social responses to achieve global sustainability.

In addition, there is greater attention to performance of government programs and the societal benefits and impacts of public investments. Pure science is no longer an adequate justification for large, expensive observing systems, such as Earth observing satellites. Similarly, GIS requires significant resources to be built and maintained. There are needs for applications and tangible, identifiable near-term uses to help justify the observing and information systems across sectors and stakeholders. There is a need to discover and demonstrate innovative and practical uses that support policy, business, and management decisions of public and private organizations. While there have been successful examples of applications, efforts to substantiate the benefits of the examples could be strengthened, particularly for quantitative determination of value and impacts.

10.2 Value of Information

As indicated at the beginning of this chapter, VOI studies have a long history, in North America, Europe, and other countries such as Australia, where government agencies have active groups looking at the impacts and benefits of their primary missions. A number of examples are given below.

Understanding how to improve decision-making and how to increase the impacts of Earth observations has been a continuing theme at NASA. For example, NASA Earth Science applications, supported by the Applied Sciences Program of the NASA Earth Science Division (http://appliedsciences.nasa.gov/), focus on agriculture, air quality, climate, disasters, ecological forecasting, public health, water resources, and weather and has implemented initial steps for evaluating the benefits and impacts of their projects.

The US Geological Survey (USGS) provides geophysical, geological, hydrological and biological sciences, geography, and remote sensing geospatial and archival data. These data are interpreted as high resolution, comprehensive maps and other forms of data and information that can be used to address land use, contamination and other local and regional needs (Bristol et al. 2012). USGS delivers all of the data and scientific information as public goods that are supplied to all customers for the cost of reproduction such as the National Map (Halsing et al. 2004).

Several other North American government and private organizations have sponsored and participated in studies of the VOI and associated socioeconomic impacts. The Geospatial Information and Technology Association (GITA), the American Water Works Association Research Foundation, the US Federal Geographic Data Committee (FGDC), and GeoConnections Canada began collaborative work in 2004 to develop Return on Investment (ROI) methodology for financial analysis of geospatial projects (Ancel et al. 2006). The methodology was further refined to include multi-agency financial analysis (Ancel et al. 2007) and to develop case study examples (Stewart 2008, 2010a, b, 2011a, b, c). These activities are further detailed in the Case Studies section of this chapter.

In Europe a major impetus towards the assessment of spatial data infrastructures (SDI) has come with the development and adoption of the Infrastructure for Spatial Information in the European Community (INSPIRE) Directive in 2007, a European legal framework requiring all 27 member states of the European Union to establish and maintain SDIs for their jurisdictions, and make them interoperable through the detailed technical specifications developed under the guidance of INSPIRE and its working groups. A study on the expected economic impact of INSPIRE was carried out in 2003–2004 prior to the adoption of the Directive (Craglia et al. 2003). A cost-benefit analysis was also performed on the Global Monitoring for the Environment and Security (GMES), a European system with a space component (the Sentinel satellites), and a ground application component (Sawyer and de Vries 2012). The European Commission has more recently funded multiple projects to assess impacts and benefits including the "Global Earth Observation – Benefit Estimation: Now, Next and Emerging" (GeoBENE 2006–2009; http://www.geo-ene.eu) and the EuroGEOSS (2009–2012).

10.3 Multidisciplinary Workshops

The above activities recognize the importance of a multidisciplinary approach to impacts analyses and decision support. Drawing in social scientists, and economists to work with scientists and engineers is necessary for comprehensive and sustainable solutions. Cross-disciplinary exchanges have been facilitated through a series of workshops since 2010, providing a foundation for an emerging community of practice. A summary of workshops objectives and outcomes are provided below. Detailed proceedings and a technical report provide additional information, and are referenced in the paragraphs below.

Washington, DC, June 28–29, 2010. This NASA sponsored workshop focused on "The Value of Information – Methodological Frontiers and New Applications for Realizing Social Benefit."

In respect to defining value, the participants agreed that value denotes a quantitative measure, preferably expressed in monetary terms, although not universally required. The advantage of having a quantitative measure is to provide a reference system to facilitate comparison, and therefore the choice, of alternative projects for decision makers. When it is not feasible to express a value in monetary terms, this can be given in the form of other measures, like number of lives saved, or improvement in the quality of the environment.

The event was an opportunity to advance a common vocabulary across social and Earth science, forming the basis for a new community of practice. The recommendations of the workshop emphasized, "*as immediate next steps, enhanced opportunities for convening economists and other social scientists, physical scientists, and program mangers from the nation's science agencies would better enable the design and evaluation of value-of-information studies.*" (Macauley and Laxminarayan 2010)

Hamburg, Germany – 2010. The "GeoValue" workshop was held at HafenCity University in Hamburg on 30th September–2nd October 2010, and was organised with the support of HafenCity University, the Association for Geographic Information Laboratories in Europe, the EC-JRC, and the University of Laval, Canada. The workshop focused on the value of geo-information, the assessment of Spatial Data Infrastructures, the socio-economic aspects of geo-information, and quantitative methods and models for impact assessment (Workshop held in Hamburg, Germany 2010, presentations and proceedings are available at http://digimap.hcu-hamburg.de/geovalue/).

The workshop addressed a variety of users and contexts of earth information. Outcomes called for more in-depth research on the role of information and related products in real life situations, a much more transparent articulation of the assumptions made so that they can be verified over time, and a greater sharing of experiences in different settings among different communities.

Ispra, Italy – 2011. A workshop on the socio-economic benefits of GEO/GEOSS was hosted on July 11–13 at the EC-JRC in Ispra, Italy. The workshop was sponsored by EC-JRC, IEEE, The International Institute for Applied Systems Analysis (IIASA) and NASA. The purpose of the workshop was to identify a program of activities to undertake during 2011–2014 to support the GEO 10-year implementation plan (www.earthobservations.org/documents) and the assessment of the benefits that can and will be achieved. Such program of activities could include the consolidation of dispersed bodies of literature relevant to the assessment of impacts and benefits of geographic information/earth observation, the evaluation of different methodologies appropriate to undertake such assessments, the gathering of evidence of impacts/benefits in different user communities and societal benefits areas, and outreach activities to develop shared understanding across disciplinary boundaries on value and methods of assessment.

This workshop developed and recommended a 4-year plan for quantifying socio-economic benefits of environmental observations. This encompassed both near term

Fig. 10.2 Boulder workshop attendees, June 2012

efforts and multi-year initiatives. In the near term, the objectives are to bring together information and processes from the active, but fragmented, international efforts for assessing the value of information (Borzachiello and Craglia 2011; Socioeconomic benefits from the use of earth-observation workshop – summary proceedings 2011).

The workshop called this “building a foundation.” In the longer term – over the next few years – the greatest needs are the creation of consistent and accepted methodologies for quantifying benefits. There must also be case studies to test and validate the methodologies. These must cover broad domains so that the formulation is not application specific.

Boulder, CO, USA – 2012. The 3-day workshop titled “socioeconomic benefits of geospatial information/GEOSS 2012” was held in Boulder, Colorado, June 12–14, 2012. It provided a forum for advances on the evolution of methodologies and presentations of relevant case studies. The workshop was sponsored by IEEE in collaboration with NASA, National Center for Atmospheric Research (NCAR), EC-JRC, GeoConnection and the Group on Earth Observation (GEO). Tutorials for non-experts were given on the approaches for assessing the value of information, the terminology of benefits assessments and examples of successful analyses. These examples included both cost effectiveness and benefit–cost analysis. The workshop included presentations and discussions of benefit assessments in North America, and provided a forum focusing on international developments. Experts in a wide range of natural science, social sciences, and communications, as well as decision-makers supported the meeting; over 80 participants attended (see Fig. 10.2).

As indicated in the summary proceedings (Pearlman and Bernknopf 2012), an outcome of the workshop is to pursue the development of a community of practice (COP) or society that encompasses a wide range of scientific, social, management, and communication disciplines. The COP would emphasize tasks, which foster collaboration across specialties and help build trust across social and science aspects. Other activities identified include an annual conference or workshop for sharing information and networking.

10.4 Technical Approaches

Systematic analysis of the benefits of geospatial information in decisions focuses on the quantitative demonstration of why and how scientific data such as earth observations has economic value. BCA of geospatial information in practical applications has its theoretical foundation in welfare economics. A BCA can be accomplished by implementing the process suggested below (Boardman et al. 1996):

- Decide whose benefits B and costs C count and select alternative geospatial information structures $\omega(i), i=1,\ldots,I$.
- Catalogue potential impacts and select measurement indicators.
- Predict quantitative impacts over the lifetime t, $t=1,\ldots,T$ of the project.
- Monetize all impacts at a discount rate r for time period T to estimate the net present value of the benefits of the project $NPVB_{\omega(i)}$.
- Sum the benefits and costs and perform sensitivity analysis.
- Recommend the alternative with the largest net benefits.

Following this approach the relationship in Eq. 10.1 is used to estimate the net present value of geospatial information:

$$NPVB_{\omega(i)} = \sum_{t=0}^{T} \frac{B_{\omega(i)t} - C_{it}}{(1+r)^t} \tag{10.1}$$

Quantification of the net value of improved information means subtracting the expected value of actions without the benefit of the information from the value of actions with the information. The net value of the new information structure $\text{VOI}_{\omega(1)}$ is the difference between the socioeconomic benefits with and without the geospatial information.

$$VOI_{\omega(1)} = NPVB_{\omega(1)} - NPVB_{\omega(0)} \tag{10.2}$$

Case studies apply the science and technology of geospatial data to inform decisions concerning the costs and benefits of economic and resource development. BCA are used to evaluate the value of geospatial information in a variety of ways. Examples of the economic impact of geospatial information have been expressed in terms of dollar savings (cost effectiveness; Stewart 2008, 2009, 2010a, b, 2011a, b, c, 2012); economic welfare improvements that reduce decision uncertainty via technological change (benefit estimation and industry studies; Bernknopf et al. 1997, 2007), and macroeconomic scenarios (Halsing et al. 2004; Craglia et al. 2003; Macauley and Shih 2010).

10.5 Case Study Examples

10.5.1 Case Study 1, Benefits of Monitoring Land Use

Moderate-resolution land imagery (MRLI) is crucial to an assessment of the cumulative, regional effect of agricultural land use and land cover on environmental (water) quality. MRLI is the primary source of information for this case study. Economic benefits accrue to the geospatial information if there is an improvement in the assessment of land use with the MRLI. The geospatial information yields a net social benefit that reflects the additional value of information MRLI contributes to solving the problem. The case study is to estimate the societal benefits of monitoring agricultural land use (Bernknopf et al. 2012) over multiple years in a regional scale model of optimal land use allocation (Forney et al. 2012). In the retrospective case study, watersheds were examined that have capability for higher intensities of crop production and higher probabilities of groundwater survivability (i.e., remaining below a regulatory threshold for nitrate pollution). The case study addresses nonpoint source groundwater pollution hazards in 35 counties in Iowa. VOI derives from increasing the production of corn while not increasing the risk to human health of contaminated groundwater. Crop production is allocated based on the relative price of corn and soy (between 2001 and 2010 corn had a higher market price), Federal and State environmental regulations, and watershed land characteristics. The MRLI in combination with groundwater vulnerability models were used to forecast the likelihood of meeting the US EPA water quality standard for nitrates in groundwater. The study was conducted for the period of 2001–2010.

The optimal land use allocation is based on the economic principle of maximizing farmer profit subject to a set of environmental constraints in 603 watersheds in northeastern Iowa. Water quality was based on 32,000 wells ranging from just below the surface to 1,220 m for period of analysis. Satellite observations, a spatiotemporal data input to the USDA Cropland Data Layer maps were linked to a groundwater vulnerability model to estimate the probability of the survivability (i.e., not exceed the drinking water quality of 10 mg/l) of a well over the next 20 years. Figure 10.3 shows the well capture zones in the region that are based on the agricultural land and nitrogen fertilizer use. Land remains as or is converted to corn if corn price is higher than soy in any given year and if the probability of exceeding the nitrate regulatory standard over the next 20 years starting in 2010 is minimal. We did not consider any other effect of corn production on ecosystem services.

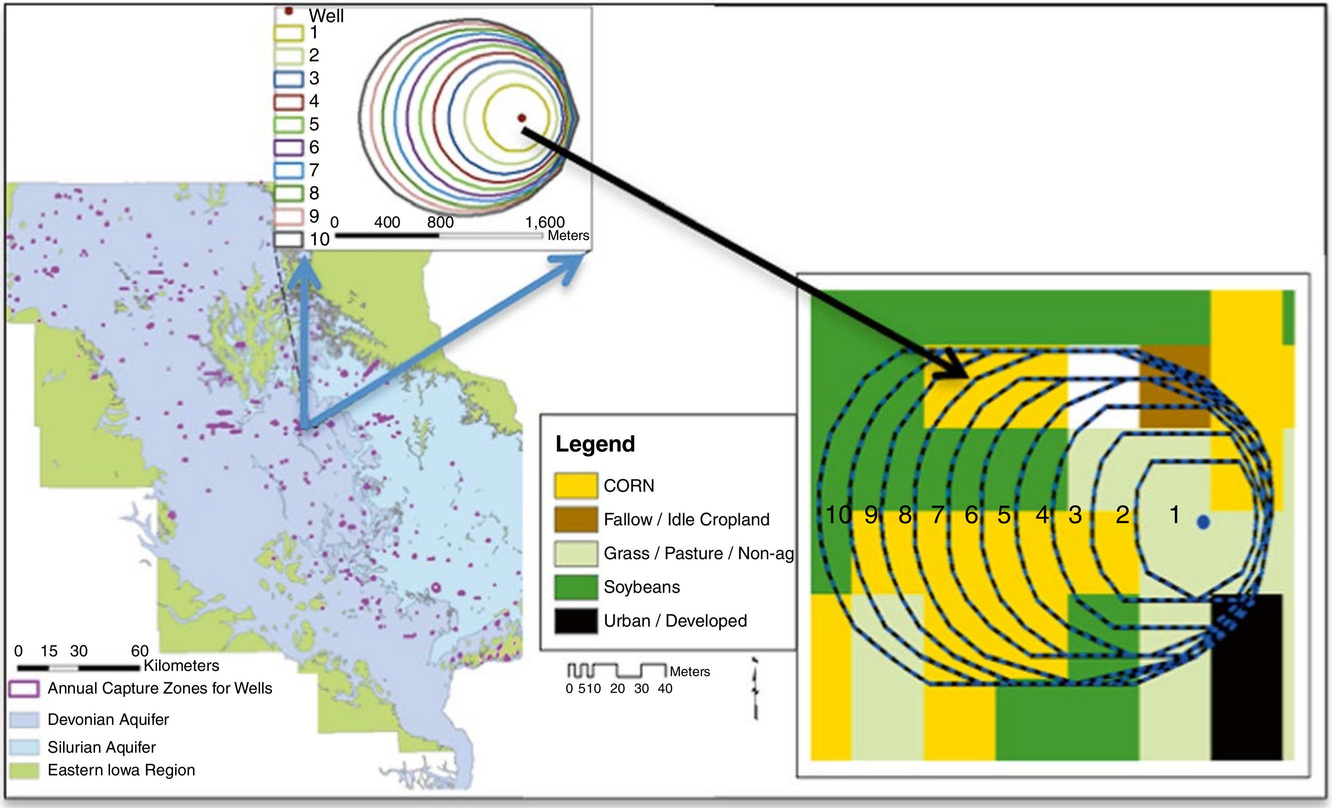

Fig. 10.3 Analyses included water quality in 350 wells in study area (Adapted from Forney et al. 2012)

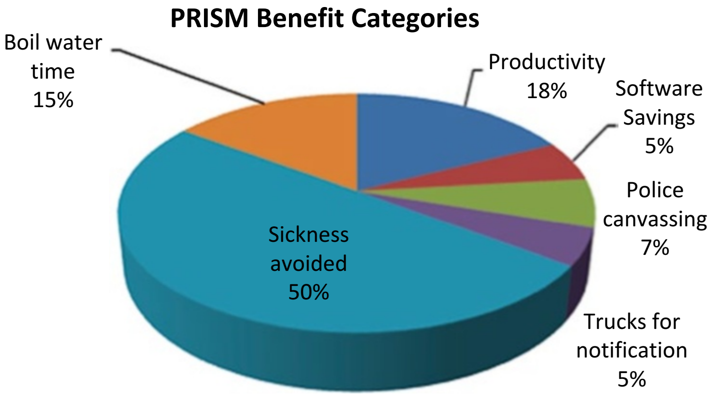

Fig. 10.4 PRISM benefit categories

The economic value (marginal benefit) of the application of the MRLI (2010 $) has a present value of $38.1B ± $8.8B in perpetuity ($858M ± $197M annualized).

10.5.2 Case Study 2, PRISM-GIS and PRISM-911: Return on Investment Analysis for the City of Quinte West and Huron County, Ontario

In 2009 GeoConnections of Canada commissioned five studies using the ROI methodology developed collaboratively with GITA in three studies in Alberta (Ancel et al. 2006). This case study focuses on PRISM-GIS and PRISM-911 applications developed by the City of Quinte West in Southern Ontario and launched in 2007 and 2008 (Stewart 2010a, b). PRISM-GIS assists First Responders during emergency situations in the field and at the Central Command Centre and facilitates communication between the field and the Command Centre. PRISM-911 provides emergency notification by telephone.

A 5-year retrospective analysis of the PRISM project showed a total investment cost of $130,757 (2006 $CA), with cumulative benefits of $405,972 (2006 $CA). Net Present Value (NPV) was $275,215 (2006 $CA), with an annualized ROI of 42.1 %. The breakeven point, where benefits equal costs, was reached in 2008, 2 years into the project. At the time of the analysis PRISM-911 had been used for 12 callout campaigns (four flooding events on the Trent River, five boil water advisories and three blue-green algae notifications). Quinte West staff had collected metrics during these campaigns (staff and equipment level of effort and population notified) that were used in the 5-year backward-looking analysis.

As shown in Fig. 10.4, public benefits dominated internal organizational benefits, with 65 % of benefits resulting from improved Boil Water Advisory communication to the public, as well as avoidance of respiratory disease due to improved

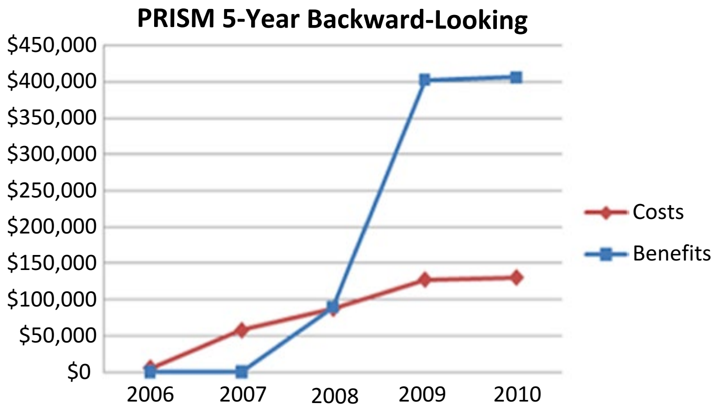

Fig. 10.5 Five-year backward-looking analysis

Table 10.1 Summary results of PRISM analysis

Study	Study	Costs	Benefits	NPV	ROI (%)	Break even
PRISM backward-looking 5 years	2006–2010	$130 K	$406 K	$275 K	42	2008
PRISM forward-looking 15 years	2010–2024	$383 K	$3.5 M	$3.1 M	54	2010
Combined 19 year	2006–2024	$517 K	$3.6 M	$3.1 M	32	2009
Combined 19 year (minus public benefits)	2006–2024	$517 K	$1.8 M	$1.3 M	13	2009
Huron County forward-looking 16 year	2009–2024	$651 K	$4.2 M	$3.5 M	34	2010
Province wide forward-looking 15 year	2010–2024	$31 M	$163 M	$132 M	29	2011
Province wide staggered implementation	2010–2024	$20.4 M	$100.2 M	$79.7 M	26	2011

public communication and perimeter control while managing toxic chemical fires. Boil water advisory notices made by PRISM-911 show savings to the public of $212,800 (2008, 2009 $CA) from rapid notification leading to avoidance of illness from drinking water exposure to *e coli* as well as rapid notification of the lifting notice saving citizens from unnecessary effort in observing boil water advisories. To estimate water advisory benefits to the public, staff experience in making manual versus automated notifications was combined with the external body of research on the costs of water-borne disease in North America, using a very conservative cost estimate of $356 per person contracting a waterborne illness (Fig. 10.5).

Huron County was Quinte West's first external client for PRISM, with a November 2009 launch. Results are summarized in Table 10.1 above. The Huron County analysis showed greater potential NPV than the Quinte West analysis, primarily a result of greater public benefits from Boil Water Advisory communication to the larger Huron County population.

A province-wide analysis extended the study to show potential costs and benefits if 50 municipalities, counties or regions adopted the system, either all at one time or as a staggered implementation. To scale municipal and county benefits to the provincial level, county and provincial metrics on disease outbreaks were collected, as well as county and provincial demographic information. A similar approach was used to scale potential respiratory disease benefits to the provincial level. Table 10.1 provides results from the municipal, county and provincial analyses.

10.6 Communicating Socioeconomic Benefits to Decision Makers

During the 2012 Socioeconomic Benefits Workshop: Defining, Measuring and Communicating the Socioeconomic Benefits of Geospatial Information, two communication experts presented approaches to improving the communication of the benefits of scientific research. Jay Guilledge, senior scientist and director of the Science and Impact Program at the Center for Climate and Energy Solutions, raised an important question in "Communicating the Benefits of Environmental Information: Whose Job Is It?" (Gulledge 2012). Currently there is a gap between the geospatial data producers (scientists) and the consumers (decision makers). This *marketplace* needs a mechanism for consumers and producers to exchange data and satisfy the demand for information.

Gulledge pointed out six aspects to consider in formulating communications – material – What information is being offered? Who is the market? What does the market value? What are the benefits of the information to the market? How does the information differentiate itself from other offerings? How will the value proposition be substantiated?

Matt Hirschland, director of communications for University Corporation for Atmospheric Research in Boulder, CO, followed with a presentation entitled "Global Forces and the Impact Research Communications Imperative." Tactics and strategy must be combined for effective communications. Strategic communications is a process directed at securing rigor and preeminence. Hirschland suggested the framework for a successful communication strategy comprises five aspects: (1) articulating key priorities and imperatives; (2) defining and understanding key audiences; (3) selecting and building distinctive messages; (4) delivering messages through the right channels and at the right time; and (5) assessing impact. To communicate science impacts within that framework, Hirschland stressed detailing the importance of our work in "stark terms measured in dollars and lives saved/enhanced."

During a subsequent breakout session of the same workshop (Boulder, USA – 2012), the participants emphasized the need for storytelling skills, and the ability to develop "elevator speeches" within the context of the above communication imperatives and framework. Good stories, with technical jargon removed, communicate well with all target audiences. The key is to present a story that shows that geospatial information distinctly improves the decision maker's situation relative to existing processes or information. The focus should be on optimizing essential activities as opposed to generic science gains. With optimization comes the highly prized *killer application*.

10.7 Path Forward

To address the viability of VOI analyses, a credible community of experts must provide consistent value to decision makers. There must be access to experts that can support application needs and deliver easily understood results. Moving in these directions requires a number of steps including identification of a body of experts, reference case studies that use accepted methods and, more generally, a community of practice to innovate and validate new applications.

During the last year, such a community has formed. A LinkedIn group, Socioeconomic Benefits Community, provides a communication tool for exchange of information. Several case studies such as those in this paper have been identified as models for quantitative assessment. In addition, a compendium of references and a web site resource are under development.

These steps are part of the initiative to build a sustainable community and pool of expertise for value of information analyses. Ultimately the scientific advances must be accompanied by improved communication and understanding of these developments. Publication of new approaches is being encouraged in both peer review journals and popular trade magazines along with presentations at major international conferences.

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Part IV
STEMming the Tide of Science Illiteracy

Chapter 11
Infusing Climate and Energy Literacy Throughout the Curriculum

Minda Berbeco and Mark McCaffrey

Energy and climate are inextricably linked, as local energy choices directly influence global climate change. Due to this powerful relationship, there is an emerging need for a scientifically literate citizenry that understands the significance of its energy choices on climate and on the other components of the Earth system in order to minimize impacts.

Climate and energy literacy is lacking in the United States both for adults and children. Though a majority of the American public recognizes that the climate is changing, a 2012 Pew survey found just 42 % of Americans believe the change is mostly due to human activity (Pew Research Center 2012). Students are not any more scientifically literate about climate and energy science than their parents, with less than 15 % of American teens reporting that they feel very well informed about how the climate system works or about the causes of climate change. Auspiciously, however, 70 % of those same teens said they would like to know more (Leiserowitz et al. 2011).

What is climate and energy literacy? This form of scientific literacy includes not only the accumulation of information about climate change and energy but also the ability to use that information for critical thinking and decision-making (Dupigny-Giroux 2008). Since decisions about energy use are rarely individual in scope, the latter necessarily includes the ability to discuss the information collectively, recognizing and discounting personal biases and interests. Thus, beyond proficiency in the sciences, climate and energy literacy requires both a sense of *agency*—a feeling that one's own decisions can affect the world—and a motivation to act upon the information in appropriate circumstances (McNeill and Vaughn 2012).

Therefore, energy-literate individuals will understand basic scientific principles relevant to making informed decisions about energy. To do this, they must

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understand how energy works, where it comes from, and how it is used. They will need to be able to connect sources and usage to environmental impacts and trade-offs. Moreover, energy-literate individuals can assess and communicate the information to others to make thoughtful decisions based in science.

Similarly, climate-literate individuals will understand basic scientific principles relevant to making informed decisions about climate change. Through their scientific understanding of deep time (time scales of millions of years), they can distinguish historical climate changes over geologic intervals from recent human-caused climate change that have occurred over shorter periods of time. Moreover, they will understand that humans can take actions to reduce climate change and its impacts.

Since both energy choices and climate change will affect students throughout their lives, it is vital to ensure they have key knowledge about these twenty-first century challenges through formal science education. Whatever role students go on to play in the political landscape—from politicians to voters, they will require the scientific background to make thoughtful decisions as adults. An investment in their education now is an investment in their future.

There are many challenges ahead. How can educators assist students in learning the basic science behind climate change science and energy choices? How can they teach students about the trade-offs inherent to energy usage and environmental impacts without accusations of political indoctrination? Moreover, where can teachers find scientifically accurate and pedagogically sound information to support a more climate- and energy-literate society? We will start to address these many and varied questions in this chapter by exploring both the barriers and the breakthroughs for greater climate and energy literacy.

11.1 Challenges to Teaching Climate and Energy Literacy

There are innumerable obstacles to attaining climate and energy literacy, ranging from emotional and psychological barriers to the sheer complexity of the science. For these reasons, educators must be cognizant of the many challenges they will face when addressing climate and energy issues in their classroom. Well-prepared teachers will create an illuminating environment for students to engage with the material without introducing misinformation or distressing students.

Unsurprisingly, one of the greatest challenges that teachers face when addressing climate and energy literacy is *science denial*, defined as the rejection of scientific information that does not match personal ideologies. A common example of science denial in the classroom is the dismissal of evidence for evolution due to religious beliefs. When related to climate change, science denial tends to be rooted in fears and deep personal values rather than in the science itself (Rosenau 2012). This dissent is not inherently anti-science, but airing it in the science classroom can confuse students' understanding of how science works by focusing on political, moral, or social debate rather than utilizing scientific evidence to support ideas.

For example, unguided discussions of climate change or energy usage can easily turn from expounding the details of the science to extolling the virtues of free market capitalism. Science teachers thus may find themselves in the middle of a debate of liberal versus conservative political values rather than a discussion of how the greenhouse effect works. Moreover, conducting or allowing such discussions can lead to teachers being accused of indoctrinating students and attempting to promote behavioral change.

Ironically, as a way of avoiding potential conflict, educators will often opt for *teaching the controversy*, allowing for a spurious debate in the classroom on the basic science of climate change, whether conducted by students themselves, guest speakers, or supplementary teaching materials like videos (which are often provided by organizations promoting climate change denial). However effected, *teaching the controversy* is both scientifically inaccurate and pedagogically inappropriate, since it misrepresents the scientific consensus on climate change. As the voice of the scientific community in the classroom, a science teacher has a responsibility to convey the scientific consensus accurately and without reservation. To do otherwise is fundamentally unfair to students, since it leads them to believe, wrongly, that the basic science of climate change is not credible or is under deliberation.

Though the science is clear, there are still many questions that students can deliberate regarding ways and means of mitigation and adaptation to global climate change. Such a debate could be responsibly addressed in a social studies course or in an advanced science class that addresses moral, political, and ethical issues after a thorough explanation of the evidence. Climate change denial itself might be responsibly addressed in such a class, too, just as the Scopes Trial and later manifestations of creationism are sometimes addressed in advanced biology or social studies courses. But, of course, such learning activities should not be used to promote science denial as though it were a scientifically valid viewpoint. Teachers should also be aware that questioning the science in and of itself isn't necessarily "denial". Given the challenges inherent in confronting student apathy, inquiry into the process of science is to be encouraged if it comes from genuine interest and not an ideological agenda.

In addition to understanding the range of science denial and being prepared to address it, educators should be concerned with the emotional aspects of discussing the potential implications of climate change, since the implications are undeniably severe. Hicks and Bord (2001) found that teachers attempting to address these issues with their classes unintentionally alarmed, dismayed, and demoralized their students. Who, after all, wants to hear that climate change is going to disrupt the human environment and affect the biosphere as a whole, or to learn that these changes are largely due to human activity? At the same time, though, Hicks and Bord argued that it would be a betrayal not to "awaken" students to current challenges posed by climate change. This is a conundrum: how can educators discuss the seriousness of the effects of climate change while not creating undue alarm or disillusionment?

One way for teachers to address potential student angst is to focus on human ingenuity, emphasizing ways in which historical environmental challenges were overcome, and discussing ways to mitigate impending changes ahead. This technique could give students a greater sense of agency when addressing a scientific challenge. The value of agency in providing the foundations for climate and energy education was further described by Ojala (2012), who found the use of *hope* encouraged more pro-environmental behaviors. Ojala defined hope in terms of creating goals, knowing a pathway towards achievement, and possessing motivation to move forward. The idea is that teachers can utilize students' hopes to promote positive thinking about solutions to climate change challenges. The objective for teachers would be to utilize this hope without giving prescribed answers to climate and energy challenges ahead.

Even those teachers who are willing to teach the scientific consensus on climate change and able to manage the psychological components often feel unready to teach such a complex topic (Johnson et al. 2008). Since climate and energy literacy have long been neglected in science education, many teachers lack the appropriate scientific background themselves. Moreover, persistent misconceptions within the teaching community are an additional hurdle. A study by Lambert et al. (2012) found that both pre-service and in-service teachers suffered from misconceptions about climate change that persisted even after they were taught about the subject. Although teachers were able to learn about the carbon cycle and causes of global warming, they continued to struggle with how the greenhouse effect worked.

The fact that such misconceptions are both prevalent and tenacious even among science teachers suggests that misunderstandings may be equally so among their students. And indeed, many of the misconceptions that teachers hold are shared by middle and high school students (Choi et al. 2010). In addition to also being confused about the greenhouse effect, students struggle to grasp ideas of the carbon cycle and human dimensions of climate change. Moreover, they often make such fundamental mistakes as conflating the ozone hole or pollution such as nuclear waste with climate change (Cordero et al. 2008; Madsen et al. 2007; for a detailed overview of common misconceptions about climate, see McCaffrey and Buhr 2008). Furthermore, students' grasp of the concept of deep time was connected to their ability to differentiate between weather and climate, a key component to understanding global climate change (Lombardi and Sinatra 2012).

Teachers, therefore, would benefit from adopting pedagogical techniques that help to identify and correct such misconceptions. In many cases, teachers have the ability to counter these misconceptions by specifically exposing and refuting them directly in the curriculum (Gautier et al. 2006). For example, when McNeill and Vaughn (2012) addressed in their classroom the common fallacy of confusing holes in the ozone layer with climate change, their high school students did not report this belief in post-course testing.

Although students' understanding of the Earth system can be both narrow and simplistic (Shepardson et al. 2009), several studies have demonstrated students may have a better understanding than their written responses suggest (McNeill and Vaughn 2012; Jakobsson et al. 2009). McNeill and Vaughn (2012) found that students who did not demonstrate a basic level of understanding of climate change in writing were nevertheless able to express a deeper comprehension orally over several survey questions. This further highlights the complex nature of climate change science, suggesting it is a topic that requires more than a few lessons. Rather, it should be integrated into a larger lesson plan.

Although climate is inherently a global issue, teachers are more likely to discuss climate change and energy choices if they have curriculum that addresses these issues from a local perspective (Johnson et al. 2008). Regional forecasts, for instance, can be helpful in showing students how climate change may affect their local communities in future decades. A useful source of regional information about the anticipated impacts of climate change is the U.S. Global Change website's (http://globalchange.gov/) Regional Climate Information tab.

11.2 Pathways to Greater Climate and Energy Literacy CLEAN: A Resource for Teachers

Since climate change and energy literacy are topics rarely integrated into current state science standards, students are reliant on pioneering teachers to bring this information to them. Although many educators may feel highly motivated to engage students in climate and energy literacy, these teachers require scientifically accurate and pedagogically usable content that fits into already established standards.

The Climate Literacy and Energy Awareness Network (CLEAN) was designed for teachers interested in addressing climate and energy literacy in their classroom. CLEAN is a project funded by the National Science Foundation that was developed by members of the Climate Literacy Network, a community of educators, policymakers, community leaders, students, citizens, and scientists interested in fostering greater climate and energy literacy. The CLEAN website (http://cleanet.org) includes a catalog of reviewed and annotated online materials that have been vetted for educators to use in their classroom along with tips for teachers on how best to teach specific concepts at appropriate grade levels.

CLEAN is a tool to help integrate climate and energy topics into already established courses, such as Earth sciences or biology. As science standards move toward prescribing integrated courses that involve multiple scientific disciplines, there will be additional changes to bring climate and energy concepts into the classroom. One such opportunity is through the Next Generation Science Standards.

11.3 Opportunities Ahead: Next Generation Science Standards

The Next Generation Science Standards (NGSS) are an opportunity to integrate climate and energy literacy into public school education across the nation. NGSS is a new set of K–12 science standards intended to provide guidance to teachers as they educate their students to become scientifically literate members of society. The standards were developed through a state-led collaboration and sponsored by the National Research Council, the National Science Teachers Association, the American Association for the Advancement of Science, and Achieve Inc. Lead states involved in the process number 26, and it is anticipated other states across the country will adopt the standards as a pioneering effort to bring science standards into the twenty-first century.

Climate change, energy, human impacts on Earth systems, and sustainability are all topics outlined in the NGSS. Climate change is addressed primarily in the Earth sciences, beginning in primary grades with the basics of seasons and how weather and climate differ, with a more specific focus in later grades on human impacts on climate and the Earth system. Moreover, the standards integrate current research methods and thinking about climate change by including evidence based analysis and asking students to model the earth system, as well as encouraging students to think about engineering solutions.

By emphasizing the science of climate and energy while addressing the context within the community and technical innovations as potential responses, NGSS provides opportunities for students to connect the science to their community. Moreover, these standards emphasize the value of technology in people's lives, how this technology supports our lifestyle, and also how it can contribute to human impacts on the environment. This brings into the science classroom the challenges both of maintaining current lifestyles in the United States and of dealing with the impacts this lifestyle can bring. A scientifically literate populace that understands the causes and impacts of climate change will be able to consider their energy usage and choices within a scientific context and make informed decisions based on accurate information.

Though the Next Generation Science Standards highlight human ingenuity in addressing climate impacts, the standards do not address specifically how students *should* respond to climate change nor do they emphasize behavioral change. Ideally, information learned in science classes can be synergistic with and complement issues learned in social studies courses to encourage students to use the science to inform policy decisions, as they would as adult decision-makers. This would give them the tools needed to engage in decision making in the future—identifying quality science, weighing their options of energy and resource usage, and making thoughtful choices for the future. NGSS is an important first step for students to learn the background information to help them make thoughtful decisions as adults.

11.4 A Common Language: Climate and Energy Literacy Frameworks

In order to talk about climate and energy literacy, a common language must be adopted. What are the common themes of these forms of scientific literacy that should be integrated throughout all lessons?

Climate Literacy: The Essential Principles of Climate Science was developed through the input of multiple scientific, governmental, and non-profit organizations, including the National Oceanic and Atmospheric Administration and the American Association for the Advancement of Science and is endorsed by the United States Global Research Program.

Although scientific understanding is an integral part of literacy, because of the strong social and political implications, climate literacy requires an integrated approach. This approach utilizes the science to inform the social and political implications. As a result, the principles of climate literacy are broken into seven topics that build upon each other, starting from the science and ending with the social and political consequences. The principles are as follows:

1. The sun is the primary source of energy and the Earth's climate system.
2. Climate is regulated by complex interactions among components of the Earth system.
3. Life on Earth depends on, is shaped by, and affects climate.
4. Climate varies over space and time through both natural and man-made processes.
5. Our understanding of the climate system is improved through observations, theoretical studies and modeling.
6. Human activities are impacting the climate system.
7. Climate change will have consequences for the Earth system and human lives.

Global Change Research Program (2009)

The Guiding Principle for informed climate decisions—which provides a societal context for the other principles—emphasizes that humans can take actions to reduce climate change and its impacts, and articulates the range of responses without advocating for a particular solution.

The Principles of Energy Literacy were developed by the U.S. Department of Energy, working with other federal agencies involved with the United States Global Research Program and numerous education partners across the country. As with the Principles of Climate Literacy, the goal of the Principles of Energy is not to enforce a specific behavioral change or political choice, but to have choices be rooted in core science to help students make thoughtful choices as adult decision-makers. It is important to give students the tools to understand science when evaluating the information.

Like Climate Literacy, the Energy Literacy: Essential Principles and Fundamental Concepts for Energy Education begin with the basic science and build to the social and political consequences of energy choices. Framed by a Guiding Principle for Teaching and Learning, energy literacy principles include:

1. Energy is a physical quality that follows precise natural laws.
2. Physical processes on the Earth are the result of energy flow through the Earth system.
3. Biological processes depend on energy flow through the Earth system.
4. Various sources of energy can be used to power human activities, and often this energy must be transferred from source to destination.

5. Energy decisions are influenced by economic, political, environmental and social factors.
6. The amount of energy used by human society depends on many factors.
7. The quality of life of individuals and societies is affected by energy choices.
U.S. Department of Energy (2012)

Ultimately, the goal of climate and energy literacy is to engage learners in the science to make thoughtful decisions about how to address and reduce the impacts of their choices. This can include energy efficiency, climate mitigation, or societal adaptation. The decision-making must be based on the science, which should be generated and assessed by the scientific community, not on the representations (or misrepresentations) of special interest or political groups.

11.5 Conclusion

Classroom conversations about climate change and energy use can challenge even the most seasoned educator. Obstacles include political and social pressure to not teach the science or to teach the controversy, the absence of these vital topics in standards or curricula, and the emotional reactions that students may have when addressing a potentially distressing topic. Moreover, many teachers feel overwhelmed or ill-prepared to teach the complex sciences involved with both climate and energy, as the topics are highly inter-disciplinary. As a result of these many challenges, some teachers may choose to avoid engaging their students in climate and energy topics. This is inherently unfair to students, as it puts them at a disadvantage relative to peers across the country where these issues are being more accurately addressed. Likewise, misinforming students about the science will stunt their ability to address challenges and choices as adults and future decision-makers.

The building blocks for greater literacy across the country already exist. The Next Generation Science Standards are an opportunity to address climate and energy literacy in public schools across the country. The Climate Literacy and Energy Awareness Network is a searchable database available for teachers to implement climate and energy literacy in their classrooms now under state standards and in the future with NGSS. Meanwhile the Essential Principles of both Climate Literacy and Energy Literacy outline the fundamental ideas and language for talking about climate and energy literacy topics. Combined, the standards, lesson plans, information networks, and fundamental principles create a foundation for teachers to encourage greater climate and energy literacy, and that, in turn, will better prepare young people for the climate and energy challenges of the twenty-first century.

As tomorrow's policy-makers, students must be able to make scientifically informed, thoughtful decisions as to how they want to spend their resources and about the associated costs with each choice. The scientific and educational communities can support these efforts by working together to promote pedagogically sound and scientifically accurate material to the decision-makers of tomorrow.

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Chapter 12
Enticing Students to Pursue STEM-Related Careers Through Cyber-Driven Learning

Gwynne S. Rife and Julie McIntosh

Faced with a changing planet and the need to understand and respond to these changes, there is a demand both for well-trained scientists and environmental educators who can offer learners quality science education. The need is crucial for the next generation of citizens who will continue to face challenges related to a changing planet (Cortese 1992; Kilduff 2008). Under the umbrella of STEM careers (Science, Technology, Engineering, and Mathematics), both formal and informal educators have overwhelming evidence that they must provide more than knowledge of these disciplines, but problem-solving ability and deeper concept understanding (Alexander 1992; Linn 1987; Yarroch 1985). Future earth scientists and professionals need to be armed not only with knowledge, but also with the skills and dispositions to be successful (Carnevale et al. 2010; Cook and King 2004; Wellman et al. 2008).

Teacher quality matters enormously for science student performance (Cochran-Smith 2003; Hanushek 1997, 1989; Lynch 2001). Students taught by more effective educators learn substantially more over the course of the year than students taught by less effective educators (Boyd et al. 2006; Desimone et al. 2002; Everston and Emmer 1982; Goldhaber and Anthony 2007; Rivkin et al. 2005; Whitehurst 2002). Effective teachers are those that keep students engaged in learning activities. Although measures of teacher effectiveness and quality are generally defined by student performance, this alone does not address the complex nature of what makes a quality educator.

Most research on educator effectiveness has focused on teacher attributes, finding that readily measurable characteristics such as experience, certification or

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licensure, and graduate degrees generally have little impact on student achievement (Aaronson et al. 2007; Boyd et al. 2008; Clotfelter et al. 2007; Hanushek and Rivkin 2006; Pascarella 1980). Relatively few rigorous studies look inside the classroom to see what kinds of teaching styles are most effective. This chapter enters the STEM classroom to consider a new philosophical approach to teaching, the new standards for science education, the importance of problem-based learning, and the value and availability of cyber-driven methods.

12.1 New Paradigm: From Sage to Guide

In science teaching, studies have investigated the relative effects of two teacher practices—lecture-style presentations and in-class problem solving—on the achievement of students in math and science (El-Khawas et al. 1998; Felder 1993; Felder and Silverman 1988; Gall 1970; Galton and Eggleston 1979; Harris 1998). The former focuses on content while the latter emphasizes process, and the studies show that in-class problem solving has a greater impact on student achievement. Unfortunately, higher education in traditional sciences has been slow to change its focus on content despite evidence that it is more effective to do so (Crawford and Deer 1993; Green 1999; Kirst and Bird 1997; Lewis 1996; Surry and Land 2000). These two ends of the spectrum have been coined *sage on the stage* (traditional lecture, teacher-centered) or *guide on the side* (facilitation, learner-centered) (King 1993; Saulnier 2009; Zohrabi et al. 2012).

This shift in science teaching from sage to guide is a difficult transition. Recognizing the value of engaging students through new methods and releasing the tight grasp many science educators have of their content are common themes at most scientific meetings. Those who have moved from this sage-on-the-stage paradigm to new ways to engage and promote concept learning have been fighting the battle to convince teachers to approach science education in ways that both empower and motivate students. With technology as a tool, the ability to do so is greatly enhanced.

Geoscience educators (with specialties such as Earth Science, Ocean Science, Environmental Science, and Atmospheric Science and now also inclusive of Environmental Education and Stewardship) have a foundation that is global and rooted in a large-scale knowledge base. Because there is so much science to integrate, educators need a framework of knowledge and a shared group of understandings upon which concepts and models can be based.

12.2 New Standards: Developing a World of Knowledge

Scientists, educators, and discipline specialists have worked to produce literacy standards and frameworks for K-12 (see Table 12.1) in the areas of Earth Science (Barclay et al. 1999; Chang et al. 2007), Ocean Literacy (Cava et al. 2005;

Table 12.1 Literacy guiding areas for formal and informal geoscience education

Standard	Sub-criteria	Website
Environmental literacy	Competencies knowledge and dispositions	http://www.naaee.net/framework
Science literacy	12 benchmarks	http://www.project2061.org/publications/bsl/default.htm
Earth literacy	9 big ideas	http://www.earthscienceliteracy.org/
Climate literacy	7 principles	http://cleanet.org/cln/climateliteracy.html
Ocean literacy	7 principles	http://oceanliteracy.wp2.coexploration.org/
Energy literacy	7 concepts	http://www1.eere.energy.gov/education/energy_literacy.html

Table 12.2 Organizations that provide standards related to geoscience

Source	URL for standards
NSES	http://www.nap.edu/openbook.php?record_id=4962&page=1
NSTA	http://www.nsta.org/publications/nses.aspx
NRC	http://www.nrc.gov/about-nrc/regulatory/standards-dev.html
AAAS	http://www.project2061.org/publications/bsl/
NGSS	http://www.nextgenscience.org/
NAAEE	http://www.naaee.net/framework
PISA	http://nces.ed.gov/surveys/pisa/pisa2006standarderrors.asp
ACT	http://www.act.org/newsroom/?utm_campaign=cccr10&utm_source=data10_leftnav&utm_medium=web
OECD	http://www.oecd.org/unitedstates/presentationofthepisa2010results.htm
NAEP	http://nces.ed.gov/nationsreportcard/achlevdev.asp
TIMMS	http://nces.ed.gov/timss/

Strang et al. 2007), Climate Literacy (Cooper 2011; Dupigny-Giroux 2008; Harrington 2008; McCaffrey and Buhr 2008), Energy Literacy (Barrow and Morrisey 1989; DeWaters 2009; DeWaters and Powers 2008, 2009a, b, 2011; DeWaters et al. 2007), and Environmental Literacy (Cole 2007).

At a national level, many organizations are contributing to new science standards (Bybee 1995, 1997; Foster 2003; Hofstein and Lunetta 2003; Layman 1996; Salter et al. 1988). The newest set of standards incorporates a greater breadth of Earth Science. An array of professional societies, government agencies, scientific community members, and others support and infuse the national science standards with principles and standards to guide educators on what content to teach.

Navigating science standards in the United States can be a daunting process (see Table 12.2). States have relied on the National Science Education Standards (NSES) from the National

Research Council (NRC 1993) and Benchmarks for Science Literacy from the American Association for the Advancement of Science (AAAS) to develop their own state guidelines, standards, and model curriculum. Efforts have been made to update these standards by the Next Generation Science Standards (NGSS). Other factors in preparing students for the workplace and making science a priority have been in the lack of achievement among U.S. students on Program for International Student Assessment (PISA) assessments and 78 % of high school graduates not meeting benchmark levels for one or more entry-level college courses in mathematics, science, reading, and English (ACT, OECD). In a global society, U.S. students need to be equipped to compete in an international market. U.S. standards need to be up to top performing countries like Singapore, Finland, Korea, Canada, and Japan. Standards in these countries are integrated with the nature of science being a focal point. Many states have developed their own standards using NRC and AAAS as a backbone along with international benchmarking with PISA and Trends in International Mathematics and Science Studies (TIMSS), as well as how students performed on the National Assessment of Education Progress (NAEP).

12.3 New Approaches: Problem-Based, Issues-Centered, and Experiential

Once the content has been identified at an appropriate level, effective education requires an instructor or informal educator to understand and be responsive to a variety of student learning styles and to be willing to use new and innovative methods of teaching that recognize these various styles (Blasé and Blasé 2003; Gibson 2001; Grow 1991; Jaskyte et al. 2009). Best Practice Geoscience teaching (Arrowsmith et al. 2005; Feig 2011; Karukstis and Elgren 2007; Semken and Freeman 2008; Zhu 2007) identifies using problem-based and inquiry-based teaching methods to address the needs of a range of student learning styles.

Problem-based learning involves students being supplied with a problem or real world scenario to investigate or address through the process of locating appropriate resources, analyzing and synthesizing data, and communicating the results. This type of learning experience often occurs in a small group format and can occur in both the lecture and lab setting, but can be facilitated by use of the cyber environment as well. In some cases, global concepts can best be shared by use of technology and multimedia presentations.

Inquiry-based learning involves students creating research questions, locating resources to address the questions, communicating the results of their investigation, and evaluating their results. This type of learning can be introduced in the classroom by delivering lectures as a series of questions, by conducting in-class debates, and via small group exercises. One type of inquiry-based lab exercise used in a first-year course involves the creation of research questions on a particular topic (e.g., earthquakes) and written answers to those questions. Independent research projects conducted by senior undergraduate students are also considered as inquiry-based learning exercises.

The many advantages of incorporating innovative methodologies in geoscience teaching such as those in Table 12.3 include enhanced student participation and

Table 12.3 Methods for learner-centered science education

Strategy	URL for method
WET	http://www.projectwet.org
PLT	http://www.plt.org
SQ3R	http://learningcenter.fiu.edu/Class%20Support2/science.pdf
5E Lesson planning	http://www.geosociety.org/educate/resources.htm
Two-column notes	http://www.readingeducator.com/strategies/two.htm
Graphic organizers	http://www.inspiration.com
Just in time teaching	http://serc.carleton.edu/introgeo/justintime/index.html
Interactive lectures	http://serc.carleton.edu/introgeo/interactive/index.html
Clicker/poll systems	http://www.polleverywhere.com
Jigsaw teaching	http://www.jigsaw.org/tips.htm
ConcepTests	http://serc.carleton.edu/introgeo/interactive/conctest.html

retention of material learned, increased opportunities for students to apply their own learning styles, development of self-confidence, and instructor engagement and development.

When teaching science, equipment and materials are not always available. Local businesses can be a place to start, but teachers may not know what to request. Two of the best resources teachers can buy are available through sponsored workshops affiliated with "Project Learning Tree" (PLT) and Project "Water Education for Teachers" (WET). Both of these resources include lesson plans that have been field-tested and require materials that are readily available.

The importance of experiential learning in science education programs is critical. When blended with an environmental approach, experiences become rich and meaningful. Students have a natural interest and curiosity of the world that surrounds them. They experience the world through their senses and explore the impact they have on the natural world. This ability to be inquisitive enhances scientific skills such as sorting, observing, grouping, and ordering objects. All of these experiences help children develop conceptions of how the world works. Hands-on activities should drive the curriculum for all ages. Students learn best through being involved in their own learning (National Science Teachers Association 2000).

Through experiential learning, students utilize the same practice research scientists use, thus increasing school science performance. "Science is essentially a way of giving meaning and structure to our world" (Tuss 1996). In order to provide meaning, teachers need to provide an environment where exploration is encouraged.

PLT uses the forest as a window to help students understand environmental concepts. The PreK-8 guide (www.plt.org) has national correlations and state correlations to standards. The emphasis for the lessons is to teach students how to think, not what to think. The methods and strategies provided follow a constructivist approach and allow teachers to differentiate instruction.

Project WET uses water systems to study Earth, Physical, and Life Science in an integrated approach. The K-12 guide (www.projectwet.org) has national correlations to standards and a worldwide network of educators and scientists. Topics include water quality, wetlands, water conservation, watersheds, sanitation and hygiene, oceans, natural disasters, ground water, and water history. The methods and strategies align with constructivist teaching. Teachers are encouraged in most states to utilize the 5E model as a scientific inquiry process to develop lessons that promote collaboration, critical thinking, problem solving, communication, and twenty-first century skills. The 5E model was developed out of the 1960s Science Curriculum Improvement Study and started with three phases: exploration, concept invention, and discovery (Karplus 1964). Several modifications have occurred over the years to develop the 5E model that includes having five phases; engagement, exploration, explanation, expansion, and evaluation.

The engagement phase motivates the student and gets them interested in the topic. During exploration, active learning takes place. Educators create hands-on opportunities for students to use process skills and tools. The explanation phase allows the teacher to be a facilitator of learning, explaining the scientific concepts the students encountered in the exploration phase. During the expansion, the educator probes for further conceptual understanding and has students apply the knowledge in a new situation. The evaluation can happen informally and formally throughout the lesson. Educators should be able to determine that the students have met the learning goals of the lesson.

12.4 New Classrooms: Flipped, Wired, and Engaged

When utilizing technology with any of the mentioned resources any methodology can be utilized with a learning management system (LMS) supported by Moodle, Blackboard, Big Blue Button, and Elluminate or Collaborate to incorporate the strategies in Table 12.3. The ever-growing availability of courses referred to as MOOCS (Massively Open Online Courses), and easy-to-use platforms like wikis, blogs, and numerous social networking sites can be leveraged to deliver a learning environment that can use traditional methodologies as well as support new ones.

Audience response systems such as clickers are effective in getting to know what students have already learned about a particular topic, quiz students on what they know, or to check understanding informally during a lesson. For educators who do not want to purchase clickers, mobile phones can be utilized in the classroom with Poll Everywhere or similar clicker methodologies (Briggs and Keyek-Franssen 2010; Woelk 2008). The advantage to Poll Everywhere is that students can use their mobile devices and do not need to purchase a clicker system.

In order to increase student comprehension as students are reading content online or in a textbook, various content reading strategies can be incorporated. These strategies can be utilized face-to-face or online utilizing Elluminate/Collaborate in Blackboard or other web-based conferencing techniques. In these settings, students can interact with the instructor, other students and even in small groups. The strategies listed below along with many others can be found in *MAX Teaching with Reading and Writing* by Mark Forget (2004).

12.4.1 Survey, Question, Read, Recite, and Review (SQ3R)

This method can be used in a face-to-face environment as well as online. An effective learning management system allows the instructor to pair students or to allow them to work in groups online. Students begin by previewing the text and making predictions in order to develop appropriate questions related to the content they are reading. As they read the content, students can actively search for answers and summarize what they read, review, and share with a peer.

12.5 Think-Pair-Share

This strategy can be used to stimulate discussion in small groups or whole-class environments. The educator can provide a topic and have students write what they know or what they would like to learn about a particular topic. They then read a selection assigned by the educator. Students pair up with a peer and share what they have learned from the reading and what original misconceptions they may have had about the topic. From pairs, topics can then be shared with the larger group.

12.6 Two-Column Notes

This is an effective strategy to allow students to critically think about the text they are reading. Students divide their paper into two columns. The left column is labeled "Main Idea" and the right column is labeled "Details". As students read and take notes, they can write down the main idea and details that follow in each of the columns. This can be varied by having students label columns "Opinion" and "Proof" when reading text that encourages critical thinking or problem-solving. Learning Management Systems (LMS) offer opportunities for collaboration, and all that is needed to support this method is a word file in a table format.

12.6.1 Graphic Organizers

This strategy can be used alongside Two-Column Notes as a way for students to represent information in a clear, logical manner. Graphic organizers help show relationships between ideas and can emphasize interrelationships in science topics. Graphic organizers can be creative in format such as a wheel, flow chart, ladder, Venn diagram, web, sequence chart, or timeline. Programs such as Inspiration (www.inspiration.com) can help students create graphic organizers electronically and then share with peers.

Just in Time teaching (Higdon and Topaz 2009; Marrs and Novak 2004) can motivate students and feedback between classroom activities and the work that students do at home in preparation for the classroom meeting. The goals are to increase learning during classroom time, to enhance student motivation, to encourage students to prepare for class, and to allow the instructor to fine-tune the classroom activities to best meet student needs. This can be called a "flipped" classroom where lectures are viewed as homework and the hands-on activities are completed during class with the instructor.

Interactive lectures (Duggan et al. 2007; Snell and Steinert 1999; van Dijk et al. 2001) encourage the instructor to incorporate engagement triggers and break the lecture at least once per class to have students participate in an activity that allows them to work directly with the material. The engagement first triggers then captures and maintains student attention, and the interactive lecture techniques allow students to apply what they have learned or give them a context for upcoming lecture material. Newcomers might want to begin with one activity during a class period, but may eventually call upon a variety of interactive lecture techniques all in one class period. Breaking up the lecture with these techniques not only provides format change to engage students, these activities also allow students to immediately apply content and provide feedback to the instructor on student understanding.

Two other methods for teaching are easily modified for geoscience. They are Jigsaw teaching (Constantopoulos 1994; Doymus 2008; Ferguson 1990; Slavin 1988,1989; Slavin and Sharan 1990) and group interactive exams (Biner et al. 1997; Fay et al. 2000; Hake 1998). "Jigsaw teaching" is a cooperative learning technique were learners each take a part of a learning set and meet with others to "piece" together a larger understanding. In earth sciences, many issues impact both local and global dimensions, breaking down the learning into manageable tasks are a useful way for students to make sense of a topic. During group interactive exams if students get an answer wrong, they seek another student with whom to discuss the problem before moving on to the next questions, so immediate feedback and deeper learning can occur. Both methods motivate and challenge students to guide their learning and spend time learning not just facts, but practice in application of science content in novel ways.

One of the most powerful new technologies in geoscience is Google Earth, which is an easy-to-use, low cost tool with many facets and layers of information available for developing learning events that have only just begun to be tapped (Almquist et al. 2012).

12.7 Conclusion

There are many supports for using cyber-driven methods to guide learning beyond geosciences content. If an educator seeks to offer well-organized inquiry and problem-based methods to guide learners, students will do more than memorize and forget the things they learned soon after. Geoscience educators both formal and informal need to help their learners develop the skills and dispositions needed to apply that knowledge to real-world issues on a global scale. A recommended sequence for an educator who is ready to change or move closer to this type of teaching would be to first consult the literacy principles and science standards identified for the particular course (see Table 12.2). Second, consider a progression of learning starting with a 5E learning cycle with special attention to technology driven supports and problem-based and inquiry structures that place the learner at the center (see Table 12.3). In taking the "Geoscience sage" off the stage and onto the sidelines in a well-informed and thoughtful way, educators can guide the next generation to become STEM professionals ready for a changing planet.

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Chapter 13
Using Video Projects in the Science Classroom

Philip D. Wade and Arlene R. Courtney

Project-based learning provides a real-world context that stimulates interest and engages students. One such project-based instructional approach uses student-created documentaries as learning vehicles in a non-science majors' energy course. Team-taught by a chemistry professor and an Earth science educator, the course is part of a writing-intensive liberal arts core curriculum for university honors students. Storytelling drives a compelling documentary and motivates discovery since the construction of a cohesive narrative involves significant research, writing, editing, and rewriting.

Along with traditional assessment methods, two knowledge surveys (pre-/post-project administration) were used. One survey focused on skills necessary for video production, and the second assessed content knowledge acquired from each documentary. Five years of experience has allowed us to enhance our approach to teaching the construction of quality videos that catalyze interest in learning scientific concepts. In this chapter, we will discuss components of student video production, assessment of the course, and instructional lessons gleaned during 5 years of implementation.

13.1 Project-Based Learning

John Dewey advocated *learning by doing*. In his 1916 treatise *Democracy and Education: An Introduction to the Philosophy of Education*, Dewey put forward the idea that if students are given something to do rather than being passive

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recipients of knowledge, the learning activities will promote thinking, and learning will naturally result. Project-based learning (PBL) is a learner-centered, comprehensive instructional approach that asks students to conduct in-depth cooperative investigations into topics of current relevancy (Moursund 2003). Such projects put learning into a real-world context giving the student a reason to want to know more about the topic. PBL projects are complex tasks involving inquiry, investigation, knowledge acquisition, and conclusion synthesis. The students make decisions and defend them. Consequently, such activities invoke higher-order thinking skills.

By constructing a personally meaningful culminating product such as a video, multimedia web document or other written/visual product and sharing it with others, students have an opportunity to demonstrate what they have learned (Kafai and Resnick 1996). Since students exercise more autonomy over their learning experience, they maintain a higher level of motivation and take more responsibility for their learning (Wolk 1994; Worthy 2000). PBL strives for "considerable individualization of curriculum, instruction and assessment – in other words, the project is "learner-centered" (Moursund 1998, p. 4).

In the typical science course, learning is teacher directed (Wieman and Perkins 2005). Students are presented with knowledge and concepts via textbooks and lectures and then given the opportunity to apply them. In a project-based learning environment, the teacher becomes a learning facilitator rather than the dispenser of knowledge. Projects in the PBL environment are not ancillary to the instruction, but rather, serve as the centerpiece through which learning occurs. Unlike direct instruction, PBL and artifact construction allow for diversity in learners in terms of interests, abilities and learning styles. While today's students are immersed in social networks and technologies outside the academic environment, often little is done in the classroom to teach the use of these connections to learn about science. Such participatory media has shifted how students think. They have "hypertext" minds. They think laterally rather than in the linear fashion encouraged by traditional instructional pedagogy (Caine and Caine 2013). New skills will be needed for success in the twenty-first century. The Common Core State Standards for Literacy in Science and Technical Subjects (2010) suggests high school students should be able to "use technology to conduct sustained research projects … using relevant information and evidence from multiple authoritative print and digital sources" (CCSS 2010, p. 66). The ability to navigate and evaluate vast amounts of information has become increasingly important. Unfortunately, not every university student has acquired these skills. To meet this challenge, students need to become fluent in the use of technology and to hone their critical thinking skills. Project-based learning such as this journalistic assignment helps students develop information-gathering skills and learn how to make sense of the information they collect. Students will need to work collaboratively and think innovatively to tackle the issues of tomorrow.

Terenzini et al. (2001) studied 480 undergraduate engineering students enrolled in traditional lecture-based engineering courses or in active or collaborative learning engineering courses and compared the students' abilities in engineering design, problem-solving, communication and group participation skills. They found statistically significant and substantially greater gains in student learning among undergraduate engineering students using active, collaborative learning approaches to engineering design, problem-solving, communication, and group participation skills compared to students exposed to teacher-centered methods such as direct instruction. The emphasis on cooperative learning in project-based instruction differentiates PBL from instruction employing either traditional or inquiry-based instruction. Project-based learning allows teachers to incorporate twenty-first century technological advances into their curriculum, not merely by layering technology onto traditional teaching methods, but rather, by allowing students to use technology as a tool to assist their learning (Richardson 2013).

13.2 Course Background

An Energy and the Environment course, uses the production of video documentaries as a PBL capstone project (Wade and Courtney 2010, 2012; Courtney and Wade 2012). The video project actively engages students in research. Students take ownership of their learning by finding, evaluating, and synthesizing information from a variety of resources and via interaction with other students and the instructors. The documentary creation process requires students to revise and reflect on their work, encouraging them to think about what and how they are learning.

The PBL project also allows students to incorporate creative aspects into their documentaries using web tools that are familiar to them in their daily lives. Moreover, the creative production process encourages the students to take ownership of their science knowledge (O'Neill and Barton 2005; Goldman et al. 2007). This project allows students to develop important life-work skills such as collaboration, communication, and critical thinking within the discipline. In this way, the instructional method helps meet Common Core Standards of getting students career-ready. The final video documentary is used to deliver knowledge to others in the class as well as members of the public, which motivates students to do high-quality work.

The Energy and the Environment course is taught during the third term of a 1-year, writing-intensive liberal arts core curriculum science sequence for non-science majors. It is part of Western Oregon University (WOU) Honors Program and is collaboratively taught by the authors, a chemistry professor and an earth science educator. This course follows two terms devoted to biological and earth science concepts. The majority of students in this course are freshmen and sophomores. Enrollment is capped at 24. The course includes traditional 2-h, hands-on lab investigations; lecture enhanced with content-rich, web-based activities; instructional tutorials focused on the use of various Web 2.0 tools; and sessions focused on enhancing the *social learning* aspects of science.

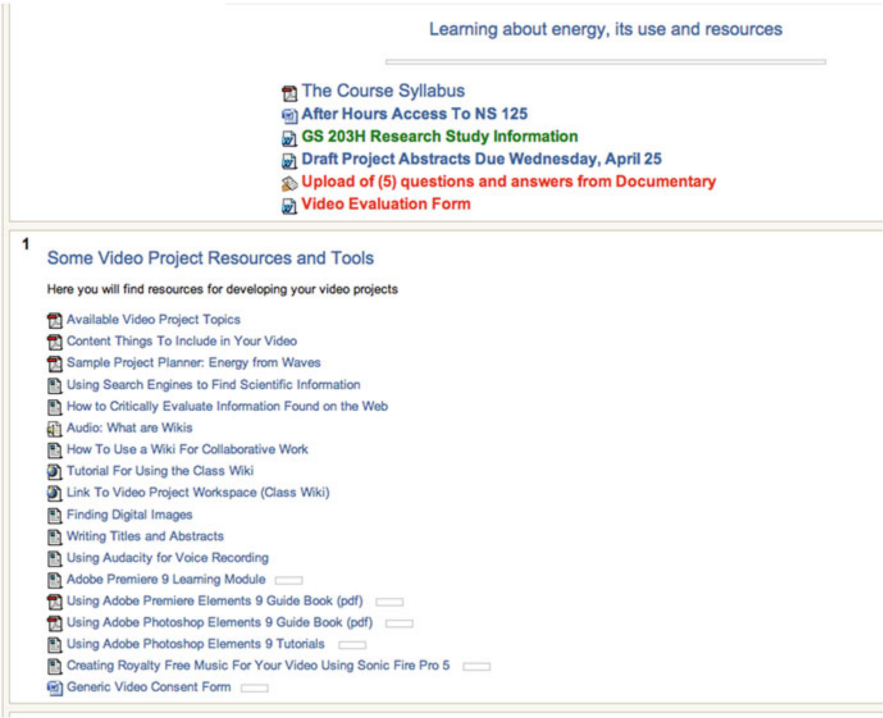


Fig. 13.1 Introductory page of class MOODLE site with list of resources and tutorials provided to assist with creating a video documentary

The Energy and the Environment course is a technology-rich course. Many social media tools are used for content dissemination, conversation, collaboration, and content creation (Richardson 2010). Examples include podcasts, video and social bookmarking for content dissemination, and a forum for conversations. A wiki was used as the primary tool for student collaboration and content creation. A course management system (MOODLE) was used to organize the various course components and web tools. Figure 13.1 shows the introductory page of the class MOODLE site with many of the necessary resources and tutorials provided to assist with creating a video documentary.

Most of the tutorials were written by the authors of this paper and include information on using the internet for research, writing abstracts, using wikis, recording voice-overs, locating imagery, and using video editing software. Students use these tools to create a 10–12-min video documentary on an energy topic as a capstone course requirement. The documentaries are presented in a professional setting at an annual, campus-wide public open house (Academic Excellence Showcase) held at the end of Spring term. Students sit in director chairs, introduce their documentary, premiere it and then answer questions from an audience consisting of peers, faculty, administrators, and members of the public at large.

13.3 Teaching Rationales

Learning outcomes of the Energy and the Environment course include:

- Increasing content knowledge of primary energy production (fossil fuels, hydro, nuclear) as well as alternative technologies (solar, geothermal, wind, wave, etc.)
- Improving communication and collaboration skills.
- Mastering the methodology for creating a video production (basic research, outline generation, writing the story, use of a storyboard, generating the narration voice-over, and editing into a final documentary).
- Presenting the work in a professional setting (including writing a proceedings abstract).

The video project incorporates the web and social media tools students use in their daily lives into their science learning. The project also shows students how social media can be used to enhance life-long learning skills. We believe social media often enhances social learning. Ormrod (1999) states:

> Social learning depends on group dynamics and how individuals either succeed or fail at dynamic interactions. Social learning promotes the development of individual emotional and practical skills as well as the perception of oneself and the acceptance of others with their individual competencies and limitations. It considers that people learn from one another, including such concepts as observational learning, imitation, and modeling. Self-efficacy levels reflect a person's understanding of what skills they can offer in a group setting (p. 39).

13.4 Course Outcomes

Students in the Energy and the Environment course shared their work during the creation of their documentaries, assisting each other with research information and technology instruction. Students learned science content from other students via sharing their documentary projects, whereas in many traditional science courses a final term paper project tends to be a solitary learning experience. In addition to the social aspects, the video project also provides enriched assessment opportunities to professors for real-time feedback during research, project outline development, narrative writing, storyboard design, abstract writing and video editing components. As instructors, we find the video projects to be more interesting to assess than traditional writing projects such as term papers.

13.5 The Video Project

Many students associate a video primarily with visual imagery and do not realize the importance of writing in the production of the documentary. Required components of the student-created video include: (a) selecting a topic, (b) conducting research,

VIEW EDIT

Sheridan and Bonnie's Project Planner-Storyboard

last edited by Sheridan Bailey 8 months, 2 weeks ago

Video	Audio
Type of Shot: Title and introduction to video/topic-- should be a text over video-type deal Description: Text reading "Biomassive Generation by Sheridan R. Bailey and Bonnie S. Wells"	Voice Over: Music: Soft, background music, Moog Funk, from the music discs Sounds: No sounds-- just beautiful, joyous music.
Type of Shot: IDK Description: pan over a corn field, or something. Geez.	Voice Over: In the last five years, we have seen a dramatic surge in public interest towards "going green". What once was thought of as a passing fad has now become a firm reality that we all must adapt to. But interest in sustainability is hardly a new phenomena. Since the late 1970s, scientists have been investigating the benefits of new avenues of renewable energy to lessen our society's reliance on fossil fuels and other nonrenewable commodities. A perfect window into the debate is through an underutilized energy resource: biomass. Drawn from multiple sources, our definition of biomass is this: any biological material that can be converted and used for fuel or energy. Music: Sounds:
Type Of Shot: Moving Trees Description: Voice Over will be played over footage that Sheridan shot on 5/9/12 outside Ackerman/ gentle area of tree. Some captions will be put on screen to highlight main dates and important info; this is a direct attempt for the viewers to be able to retain some of the historical info. (NOTE: there is more historical event that will be added to the documentary--- just in other sections or at other points!)	Voice Over: History Segment The roots of American Biomass use can be traced back to settlers, who burned wood and buffalo chips as fuel for fires. Unfortunately, the settlers can't take credit for the invention: humanity has been burning things since the dawn of time. Why, even the term "Biomass" has been thrown around since 1975, with no single person able to take credit for coining the term. The history of refined Biomass starts in 1812. A factory in

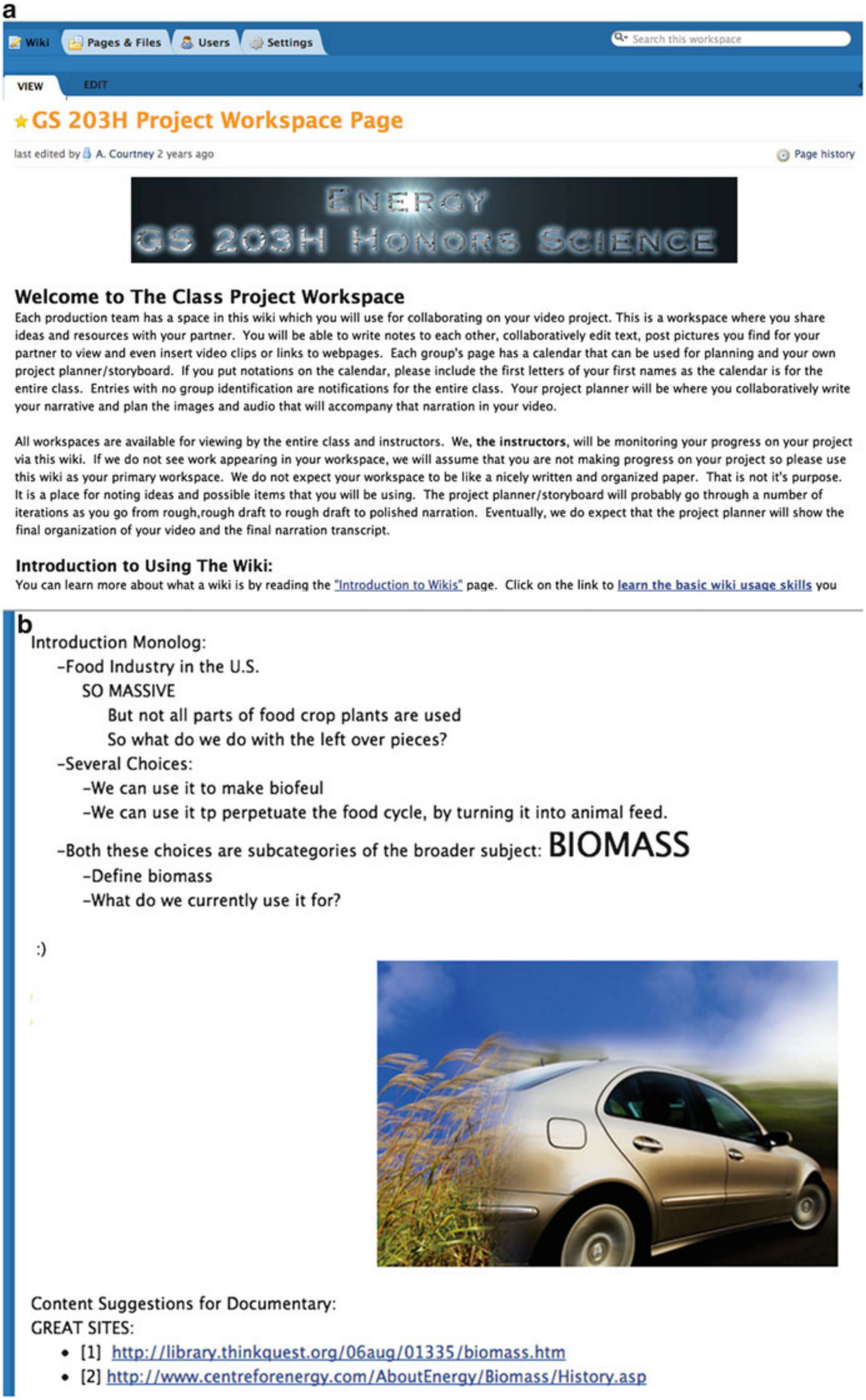
Fig. 13.2 Sample segment of a storyboard

(c) developing an outline, (d) writing a narrative, (e) constructing a project storyboard, (f) shooting or legally acquiring video footage and still images, (g) recording the narrative voice-over, (h) combining video and audio elements to construct the video, (i) editing the video and (j) rendering the project into a finished product.

The early phases of a video project are similar to a more traditional research assignment such as a term paper. First, the production team selects an appropriate topic, one that has a story that can be told within a definite time constraint and is of academic interest to the course curriculum. Our class videos are specified to be 10–12 min in length.

Once a topic has been selected and approved, the students conduct research. This research involves not only learning about the topic, but also involves finding compelling images and video footage. During this phase of the project, we provide instruction about how to use search engines and scholarly databases to find scientific information and how to find visual media, particularly content of creative commons accessibility.

After the students have had time to survey the information available about their topic, they draft an outline and begin to populate a project storyboard. The storyboard lays out a detailed production design for the documentary. It contains detailed information for every sequence in the program including both the audio and video components. A sample segment of a storyboard is shown in Fig. 13.2. As their research progresses, the production teams collaboratively write and rewrite a narrative voice-over for their documentary. All collaborative research, writing, and storyboard design is done within a class wiki (Fig. 13.3) that is accessible to all members of the class and the instructors.



a

Wiki | Pages & Files | Users | Settings

Search this workspace

VIEW EDIT

★GS 203H Project Workspace Page

last edited by A. Courtney 2 years ago

Page history

ENERGY
GS 203H HONORS SCIENCE

Welcome to The Class Project Workspace

Each production team has a space in this wiki which you will use for collaborating on your video project. This is a workspace where you share ideas and resources with your partner. You will be able to write notes to each other, collaboratively edit text, post pictures you find for your partner to view and even insert video clips or links to webpages. Each group's page has a calendar that can be used for planning and your own project planner/storyboard. If you put notations on the calendar, please include the first letters of your first names as the calendar is for the entire class. Entries with no group identification are notifications for the entire class. Your project planner will be where you collaboratively write your narrative and plan the images and audio that will accompany that narration in your video.

All workspaces are available for viewing by the entire class and instructors. We, **the instructors**, will be monitoring your progress on your project via this wiki. If we do not see work appearing in your workspace, we will assume that you are not making progress on your project so please use this wiki as your primary workspace. We do not expect your workspace to be like a nicely written and organized paper. That is not it's purpose. It is a place for noting ideas and possible items that you will be using. The project planner/storyboard will probably go through a number of iterations as you go from rough,rough draft to rough draft to polished narration. Eventually, we do expect that the project planner will show the final organization of your video and the final narration transcript.

Introduction to Using The Wiki:

You can learn more about what a wiki is by reading the "Introduction to Wikis" page. Click on the link to learn the basic wiki usage skills you

b

Introduction Monolog:
-Food Industry in the U.S.
SO MASSIVE
But not all parts of food crop plants are used
So what do we do with the left over pieces?
-Several Choices:
-We can use it to make biofeul
-We can use it tp perpetuate the food cycle, by turning it into animal feed.
-Both these choices are subcategories of the broader subject: BIOMASS
-Define biomass
-What do we currently use it for?

:)

Content Suggestions for Documentary:
GREAT SITES:
- [1] http://library.thinkquest.org/06aug/01335/biomass.htm
- [2] http://www.centreforenergy.com/AboutEnergy/Biomass/History.asp

Fig. 13.3 (**a**) Introductory page to the class wiki workspace. (**b**) Example of student class wiki workspace page

Table 13.1 Components of the video project

Select topics	Record the narration voice-over
Conduct research	Combine video and audio into a cohesive unit
Develop and outline	Add background sounds/music/transitions/titles
Write and rewrite the narrative	Edit, edit, edit
Write a proceedings abstract	Render final edit into distributable form (.mp4)
Shoot video and still footage/acquire rights to footage produced by others	

This is the point in the process at which a video project diverges from a traditional term paper-type assignment. Production teams shoot video footage and still images. If they wish to use footage or images produced by others that are not in the creative commons, they learn how to acquire the rights to those materials. Once the project storyboard is completed, and the narrative and visual files are organized, students record the narration voice-over, which provides the backbone of the production. At this point, all video, still imagery and voice-over elements are combined into a cohesive unit in a video editing program. Background sounds, titles, transitions, and music are added and the production teams edit their video through several drafts before finally rendering it into a distributable form (in our case mp4 files). Table 13.1 shows the components of student-created video documentaries.

13.6 Lessons Learned

Five years of trial and error in utilizing documentary video production as a learning tool in our science classroom has taught us a number of lessons. We will enumerate some of these lessons below. First we note that our class is a specialty class within the general education curriculum at our institution and has an enrollment capped at 24 students. This type of project will be more challenging to do in high enrollment classes because a significant amount of individualized teacher support is needed by students in the early stages of the video editing portion of the project. Table 13.2 shows a list of lessons learned from a video project.

13.6.1 Lesson #1: Group Work

We have used a two-person team approach in our classroom. Our institution employs a 10-week quarter system instructional term. We have found that there is too much work involved in the documentary for it to be a single student's project. Additionally, we have observed that those students who have requested to work alone are the students who would most benefit from developing their collaboration skills. When we have allowed for larger group projects, we have tended to see an unequal division of labor among members of the group. The video editing part of the project is a good example of an activity in which two is company, and three is a crowd! Only one person physically can edit at a time.

Table 13.2 Lessons learned from the video project

The good	The "Not so Good"
1. Use a two-person team approach	1. Single student or work in larger groups have produced lower quality projects
2. Have Students select topics from an extensive prepared topics list	2. Student generated topics often are: (a) too general, (b) too niche or (c) lack available necessary research resources
3. Use a common file sharing location (class depository) for all work	3. Student use of personal data storage areas limits access for instructors and partners
4. Use a wiki for class communication and sharing of information	4. Not using a generalized "bulletin board" approach for information sharing reduces social aspect
5. Provide instruction on the need for and how to acquire rights for the use of non-creative commons materials	5. Students are either not familiar or do not buy into copyright issues
6. Require use of specific software by all students for both audio and video editing. We use Audacity and Adobe Premiere Elements	6. Allowing a variety of different software options to be used produces frustrating technology issues
7. Set "early" deadlines for drafts of outlines, narrative, storyboard and abstract	7. Last minute work leaves little time to provide feedback, direction and fix technical issues
8. Provide multiple opportunities for video draft screenings	8. Screening of videos "on the large" screen often shows areas in need of improvement

13.6.2 Lesson #2: Topics List

It works best for us to have our students select topics from an extensive prepared topics list. Often we have found student-generated topics to be either too general, too niche or lacking in the availability of research resources. We do keep the option open for students to pursue a topic not covered on the published list, but teams must prove that there are sufficient resources for the topic and that it is a topic that has high educational value for the class in general. Once a team chooses a topic, we give them free license to approach the topic from any perspective they might choose. We do monitor the progress of each group to help them keep adequate breadth in their documentary.

13.6.3 Lesson #3: Class Wiki

Having students use personal data storage media or areas limits access for their partners and makes instructor project monitoring problematic. We set up common information and file sharing locations into which all work must be deposited. We use a class wiki for information sharing. We also set up a class folder on one of the university's servers so that all electronic media is stored in one place.

13.6.4 Lesson #4: Social Learning

We want to promote a social learning aspect to our project-based curriculum. To do this, a generalized "bulletin board" approach for information sharing was found to be most effective. Originally we tried to use blogs for class communication and a social bookmarking site (Diigo) for reference sharing, but now, we use a class wiki for all information sharing. We have found the ability for all students to leave messages, links, and perform edits in a wiki allows for better give-and-take among teammates, the class, and the instructors. In our wiki, each production team has its own section, and all students have access to everyone's information storage area for both reading and editing. Each team section is comprised of a general work area, an abstract preparation area, and the project storyboard. Teams may add whatever other pages and subsections that they wish to their area. All students having access to everyone else's wiki area allows for give-and-take not only between project partners, but also, between different project groups. If students find a resource that they feel would be of interest to the team working on a different topic, they can leave a message or link in the information storage area of that other group. We do limit reading and writing access on our wiki to members of the class and the instructors.

13.6.5 Lesson #5: Creative Commons

It is essential to provide instruction on the "need to" and the "how to" acquire rights for the use of non-creative commons materials. If you can "right-click" and save it, you own it, right? Unfortunately, that seems to be a pervasive view today. Students either are not familiar with or do not buy into copyright legalities. We show students how to locate materials in the creative commons. We also maintain a small collection of royalty free materials for student use and help them seek the rights to copyright materials as needed. Understanding copyright rules is a valuable skill that students should have for their professional growth.

13.6.6 Lesson #6: The Technology

In our experience, project execution proceeds much more smoothly if all students are required to use the same software packages for both audio and video editing. If some students use iMovie for the Mac and others use Movie Maker in the Windows environment, technological nightmares ensue. You, as the instructor, should be familiar with all the software that your students will use to generate their documentaries. When technological difficulties arise, the students will expect you to be able to troubleshoot them. Our laboratory utilizes the Windows environment, so we use Adobe Premiere Elements for video editing and Audacity for making audio tracks.

We have chosen Audacity because it is freeware available for use on different platforms. Premiere Elements is available for use on Macs as well, although there are a few differences between the two platforms. The combination of Audacity and Premiere Elements can provide a multi-platform experience if you do not want to limit your students to a single platform.

13.6.7 Lesson #7: Program Tutorials

Familiarizing the students with the software they will use to edit their projects is very beneficial. We provide our students with short video tutorials showing the basic usage of the audio and video-editing software. Although we have made our own tutorials, there are tutorial resources for both Premiere Elements and Audacity available online or on DVD that can be used for this purpose. We require our students to put together a 1- to 2-min video short demonstrating that they can incorporate video clips, still images, voice-over, titles, and transitions into a video and render it into a playable video file. We have found that if students have done this exercise early in their project development phase, they approach the video editing phase of their documentary with much more confidence than was demonstrated before we added this requirement to the project.

13.6.8 Lesson #8: Draft Deadlines

Students by nature tend to be procrastinators. We have found that it is necessary to set and enforce aggressive deadlines for drafts of outlines, narratives, the storyboard, and project abstract. If students are not given 2 or 3 weeks to assemble and edit, they will not produce a quality project. If the videos are to be shown to a group on “the big screen”, students should have several opportunities to view their draft videos in this mode. Watching the videos in a theater-like setting is where they will clearly see and hear any imperfections.

13.7 Assessing the PBL Experience

Incorporating technology and projects into the classroom is admirable, but the big question is “Did the students learn anything?” To answer this question, we administered two knowledge survey instruments. “Knowledge surveys provide a means to assess changes in specific content learning and intellectual development” (Nuhfer and Knipp 2003, p. 1). In a knowledge survey, students rate their confidence to answer a question or perform a skill. The student rating choices are: (A) the student feels confident to answer the question or perform the skill at a proficient level, (B) the student feels confident to answer at least 50 % of the question or could quickly get the information needed to answer the question or perform the skill at a satisfactory level, (C) the student has little confidence to adequately answer the question or perform the skill at a minimal level, and (D) the student is unfamiliar with the content of the question or does not possess the skill. Each survey was conducted both pre- and post-project. Survey #1 focused on the technology skills that students need to research and produce their video documentary. Survey #2 assessed the student's scientific content knowledge. An open-ended survey was also administered post-course to solicit student views on how the video project aided their learning of energy concepts. We also evaluate mastery of course content via traditional assessment instruments such as exams, homework assignments and discussion forums. Most of our students demonstrate higher mastery of content as measured by traditional instruments than students in classes before the introduction of the project-based learning instructional mode.

13.8 Knowledge Survey Results

Figure 13.4 shows a selection of sample knowledge survey data. Before producing the documentary, few students choose choice A (student was confident) for technology skills such as using a wiki, creating a storyboard, or capturing the elements of video and audio and working with them in a video editing program. After completing the project, almost all students responded to those questions with choice A. We also see the majority of students choosing choice A on content survey questions. In our classroom some of the content is delivered traditionally through reading and in-class delivery with the remainder through documentary viewing.

13.9 Student Reflections

In addition to the knowledge surveys and traditional assessment methods, we administer an open-ended survey at the conclusion of the course. Over the last 4 years, usually either one or no students indicate they would have preferred a more traditionally structured course. Students indicate that working on the project encouraged them to take responsibility for their learning and go beyond the superficial. Below are the two survey questions and some sample student responses.

Content Question: Did you increase your science knowledge of alternative energy technology by taking this class and by working on your documentary project? Please provide evidence to support your view.

Video Project Question: Given a choice between a traditional science "lecture/lab"-based curriculum or the documentary project-based class which would you choose and why?

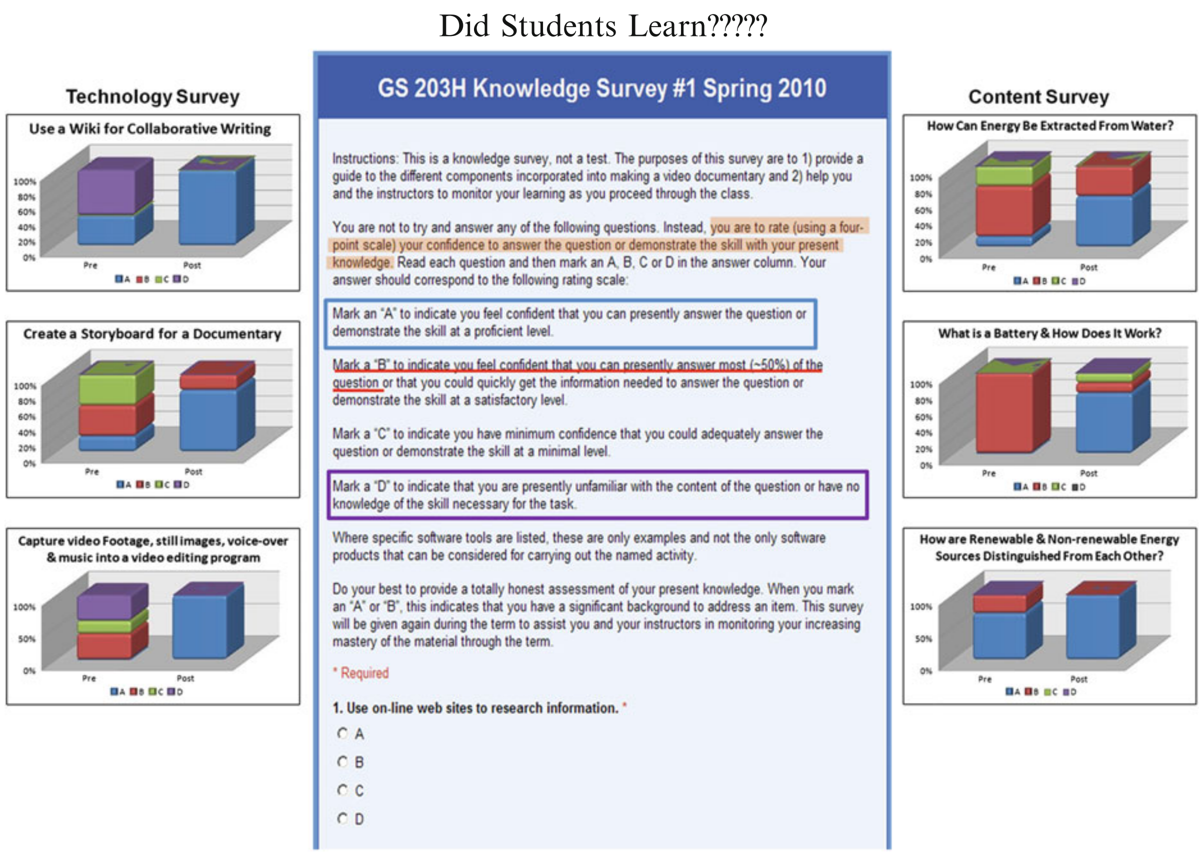


Fig. 13.4 Example of knowledge survey construct and results of knowledge survey data

Student S

Content: "I most certainly increased my knowledge of renewable resource technology. When we first began the class, I felt overwhelmed by phrases such as "photovoltaic" and by the end, I could explain exactly how power is collected from the Sun … and converted into electrical energy and saved within a battery. I know more about wind, waves, tidal energy, biomass and even tax incentives."

Video Project: "The documentary is definitely preferable to a lab/lecture for me because it is more interesting. I was able to explore something that I wanted to know more about, instead of being dictated to about what I should know. I feel that passion is a very valuable thing within a learning environment… If you want to know more about something, you are more apt to explore it in different ways."

Student J

Content: "I definitely increased my science content … I've always had a loose grasp of scientific knowledge and learning (via this video project) really helped me understand the concepts … because it wasn't something that I just had to find the answer for and then forget about. I really had to know my stuff … in order to fully represent the topic in the documentary. I had to delve deeper."

Video Project: "I liked the video project because lectures go over my head and rarely involve the student at all. Instead of having a teacher talk at us we had to brave the unknown waters on our own, somewhat. It was nice to learn what I could do as far as research and video go."

Student D

Content: "I feel my knowledge about biodiesel (project topic) definitely increased. However, I feel the information that we covered on other alternative resource topics was rushed and so I was not able to absorb the information as well. If we had (more) time to discuss each resource in class, rather than (answering chapter homework) it would have been more effective. Nonetheless, I did enjoy researching my topic and I found a lot of new and interesting information about biodiesel."

Video Project: "… given a choice between a traditional science class and the documentary approach I would choose the latter, although I would not completely exclude the first. I like covering material in a lecture format while still … working independently on my own chosen project."

Student A

Content: "Throughout the term, I definitely increased my knowledge of alternative energy technology. Coming into the class, I had very little knowledge of alternative energy technologies. Most of my learning came through creating my documentary. Having to research a specific alternative energy topic required me to learn about the technologies in order to create an accurate video and to also be able to answer any questions that were asked during the presentation of the video. I learned more from the documentary (creating and watching) process than from the (traditional) answering chapter homework part of class because I remember (was invested in) what I learned via the documentaries."

Video Project: "On the first day of class, I'll admit I was dreading the fact that this class was "documentary" project-based rather than a traditional "lecture/lab" setting. However, this was because before the class I had never made any type of video, and I am used to the lecture/lab setting. I felt like I knew how to do well in a lecture/lab setting. After completing the course, I would say that I would choose the "documentary" project -based curriculum for this class. It was a nice change from the traditional curriculum, and it allowed us to do traditional research/learning but present it in a new and interesting way. It allowed for creativity and ownership over the project. I did not feel like I lacked any learning in the class, and although at times the project was stressful. I consider it to be a great learning experience."

13.10 Conclusion

The video project allows the incorporation of a strong writing component into the science classroom. There is far more writing and revision done while developing the project than students would do in preparing a traditional term paper. The writing component of our course becomes a social learning experience rather than a solitary one. Today's student needs to be technology savvy. Although the pace of technological advances is skyrocketing, every form of technology that students learn gives them skills and confidence to tackle other new technologies. Comfort with engaging technology is an important life skill.

Our project-based learning approach encourages students to take ownership of their mastery of science concepts. Our content assessment shows student demonstration of the basic science components of the course has increased. Production of the video documentary allows students to instill creative aspects into their project. This is especially motivating for students whose academic interests lie in the creative arts, humanities, social sciences, and education. Having students teach other students is effective. In our course, each production team develops questions from their documentary for the final exam, and this encourages everyone to learn from the research of others. Students watch each other's videos, ask questions, and participate in discussions.

Lastly, our students take great pride in their documentaries, which 'premiere' to a full auditorium during Western Oregon University Academic Excellence Showcase. We also post the videos on a public Vimeo site, display them in the lobby of the Natural Science Building, and show selected videos on the university TV network. Our students educate themselves and the public about important energy issues.

Do we ever envision going back to a traditional lecture/term paper-style course for our writing intensive, non-majors science offering? The answer to that question is definitely no! We are sold on student-generated documentaries as a motivational learning tool. When we first envisioned this project in 2008, we gave students the choice of illustrating their research via a video project or a PowerPoint slideshow.

Intimidated by the unfamiliar, all students chose PowerPoint. Since 2009, however, we have required students to create a video production. To date, students in this course have produced 30 documentaries about energy and the environment, videos that have been shared with countless others at school, at home, and online.

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Part V
Organization for Resources and Resiliency

Chapter 14
Stakeholder-Driven Research for Climate Adaptation in New York City

Nir Y. Krakauer

New York City (NYC) is the economic, cultural, and financial center of the United States. Favored by its geographic location at a harbor and river mouth, NYC has maintained its status as the country's most populous city since the first census was held in 1790. Over this time, NYC's population increased more than 100-fold to over 8 million, with 19 million people in its metropolitan area (Solecki 2012). Much of the city's key infrastructure, including roads, subways and commuter trains, airports, water supply and treatment facilities, and electricity distribution network, was built during the first half of the twentieth century, and since then most of the available funding has been used to maintain and repair the existing network (Griffis 1996). The devastation of parts of that infrastructure under (post-)Hurricane Sandy at the end of October 2012 has again drawn attention to the city's lack of readiness for weather extremes, the risk for many of which appears to be increasing under anthropogenic global warming (Barnett et al. 2006; Min et al. 2011; Sillmann et al. 2013).

Here, after a brief overview of New York City's geography and climate, I will discuss how climate and extremes have been changing over recent decades. I will summarize past and ongoing research programs that seek to better understand the city's vulnerability to climate change or to develop adaptation strategies, with an emphasis on research undertaken in partnership with stakeholders such as city agencies, utilities, and insurers. I will conclude with suggestions for future research directions and lessons from New York City's experience which may be applicable to other places.

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14.1 New York City's Geography and Climate

New York City is primarily an island city, with most of the population living on Manhattan, Staten, and Long islands. Out of the five boroughs, only the Bronx is mostly on the mainland. The city is low-lying, with around 5 % of its area within 1 m of sea level and maximum elevations below 100 m. Many neighborhoods and tunnel entrances are within 3 m of sea level, as are the city's airports and sewage treatment facilities.

New York City has a humid subtropical climate, with a mean annual temperature of 13 °C and pronounced seasons moderated by the adjacent ocean. There are around ten wet days per month throughout the year, with 1.3 m/year precipitation and 0.7 m/year snow.

New York City has an unusually safe, reliable, and inexpensive water delivery system for a city its size. Built between the mid-nineteenth and mid-twentieth centuries, this consists of dammed reservoirs in protected hill watersheds in upstate New York with water flowing down into the city via aqueducts and water tunnels. The area of the contributing watersheds, which are either owned by the city directly or managed by it to maintain water quality, is several times that of the city itself. There is also a water intake from the Hudson river for emergency use.

14.2 Climate Change in New York City

The longest climate record in the city is the weather station in Central Park, maintained since 1876. This shows very pronounced warming of winter low temperatures by more than 5 K (Fig. 14.1a). Summer hot extremes have also warmed in recent decades, but have not yet regained their 1930s peak (Fig. 14.1b). The pattern seen of winter temperatures warming faster than summer and nighttime (daily minimum) temperatures warming faster than daytime (daily maximum) values is one that is widespread in the region (Betts 2011; Krakauer 2012). In addition to global warming due to increasing concentrations of greenhouse gases, the temperature records may also show the influence of regional climate forcing due to anthropogenic aerosols, which may account for the cooling seen between about 1940 and 1970 (Baines and Folland 2007). As well, there may be local climate forcing due to the urban heat island effect (Bornstein 1968), although for weather stations sited in parks, the urban heat island seems to have negligible impact on annual mean temperature (Peterson 2003; Hausfather et al. 2013).

Precipitation in New York City increased abruptly soon after the area's drought of record (1963–1965), and is now at remarkably high levels some 25 % above those typical before 1970 (Fig. 14.2a). Similar trends are seen on a regional basis (Krakauer and Fung 2008). The heaviest daily precipitation, which causes flash floods and combined sewer overflows (Willems et al. 2012), has increased proportionally faster (some 35 %, Fig. 14.2b), broadly consistent with national and

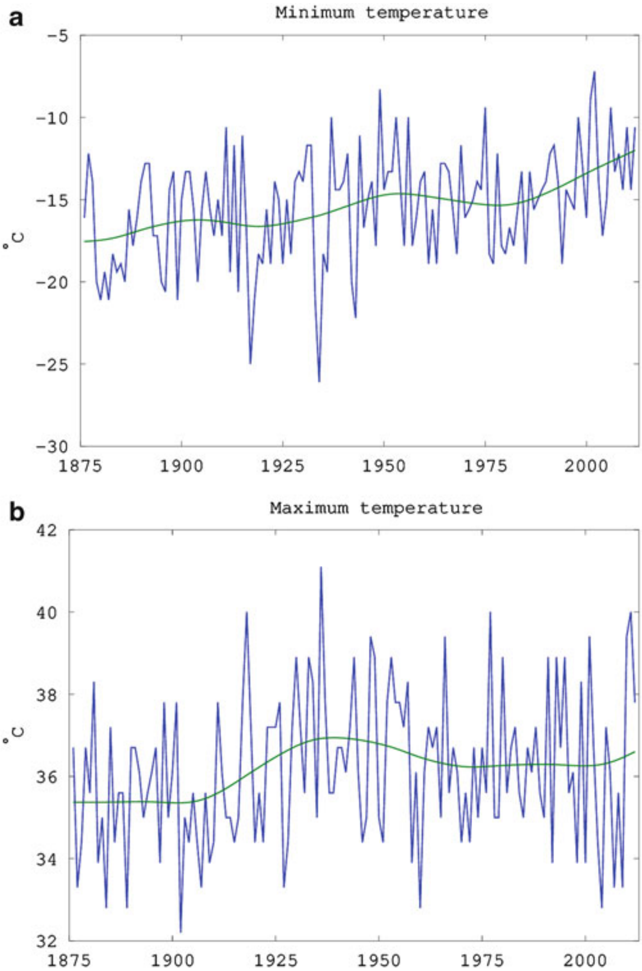


Fig. 14.1 (**a**) Annual minimum temperatures in New York City. (**b**) Annual maximum temperatures. The smooth curves use cubic splines, as in Krakauer and Krakauer (2012)

global trends (Donat et al. 2013) and expectations for trends under global warming (Min et al. 2011; Trenberth 2011).

Mean sea level measured at the Battery, on Manhattan's southern tip, has increased some 50 cm since the mid-1800s, of which 25 cm has been since 1950 (Fig. 14.3a). The recent rate of increase has been 3 mm/year, comparable to the global mean. As a result of changes in ocean circulation driven by global warming, the region is projected to face sea level rise that is faster than the global mean in the coming decades (Yin et al. 2010), with a further small contribution from postglacial subsidence. The more relevant quantity for determining flood damage is the maximum sea level in a time period, which occurs during storms and is also affected by the tidal range

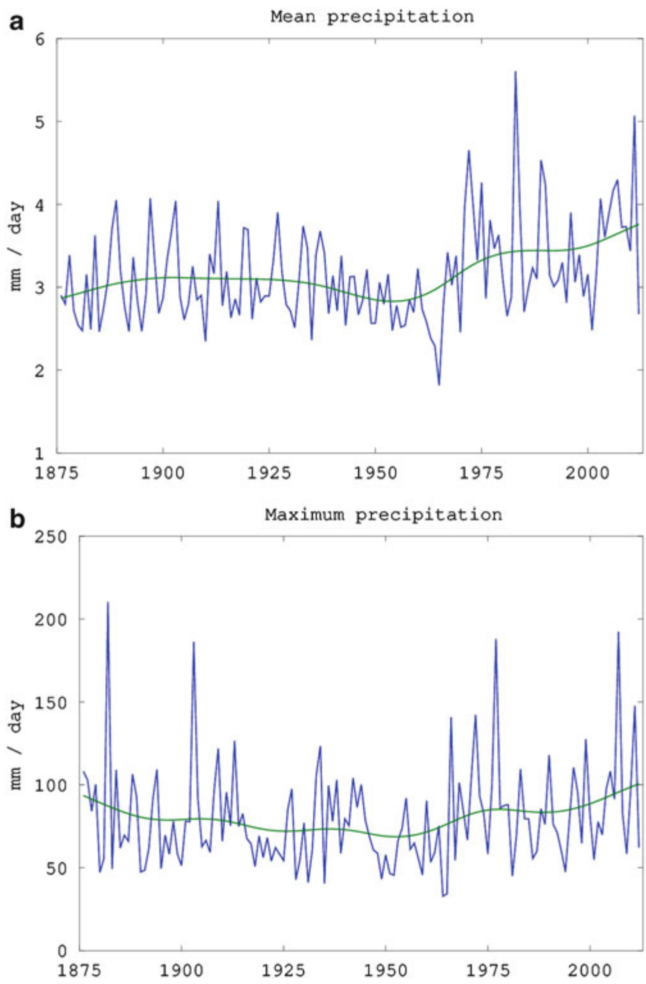
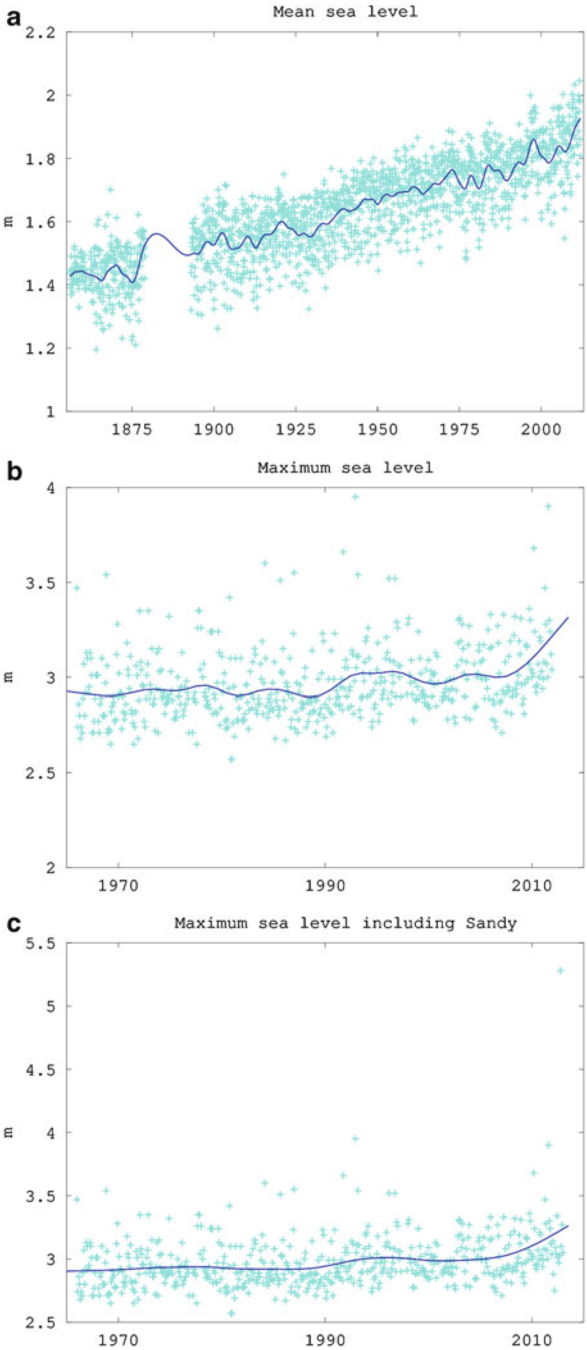


Fig. 14.2 (**a**) Annual precipitation in New York City. (**b**) Maximum daily precipitation

(which is about 1.5 m). The monthly maximum sea level has shown little trend from the 1960s until the mid-2000s. Over the last few years, even before Hurricane Sandy in October 2012, several particularly high surges were recorded, suggesting that the area that may be expected to be flooded on a yearly basis is expanding (Fig. 14.3b). Hurricane Sandy's storm surge was far above the range of the period of record (at least since the mid-nineteenth century) (Fig. 14.3c), and its storm surge magnitude had previously been estimated to have a return interval of some 500 years (Lin et al. 2012). However, placing it within this recent increasing trend makes it more plausible that we will see additional flood events of similar magnitude in the upcoming years. This trend toward higher storm surges in recent years may be linked to shifting storm tracks and characteristics due to Arctic sea ice loss, which sharply worsened over the same period (Francis and Vavrus 2012; Greene et al. 2013).

Fig. 14.3 (**a**) Mean sea level. (**b**) Monthly maximum sea level through 2011. (**c**) Monthly maximum sea level through 2012 (showing the storm surge due to Hurricane Sandy; note the change in vertical axis scale)



14.3 Climate Change Vulnerability and Adaptation Assessments

As part of the First National Climate Assessment, published in 2000, extensive investigations were made on climate change impacts and hazards for the Metropolitan East Coast (MEC), the New York City metropolitan area (Rosenzweig and Solecki 2001). Gornitz et al. (2002) projected sea level increases of 11–30 cm beyond late twentieth century levels by the 2020s, 18–60 cm by the 2050s, and 24–108 cm by the 2080s, resulting in loss of coastal wetlands and increased flood hazards for near-coast buildings. Assessment of regional sea level rise impact continued under the U.S. Climate Change Science Program (CCSP 2009) based on detailed coastal elevation mapping (Weiss et al. 2011; Shepard et al. 2012). Blake et al. (2000) and Frei et al. (2002) investigated the impact of global warming on New York City's water supply, finding that substantially decreased runoff by the 2080s is possible due to increasing evapotranspiration due to warmer conditions year-round.

New York City and its municipal agencies began to together address the impacts of climate change as part of PlaNYC, launched by Mayor Michael R. Bloomberg in 2007 to prepare the city to handle the increased population expected by 2030 while improving quality of life and reducing negative environmental impacts. Climate Change is one of the 10 "areas of interest" in PlaNYC. In 2008, Bloomberg convened a Climate Change Adaptation Task Force, consisting of representatives from city and state agencies as well as private companies that operate infrastructure, "to develop adaptation strategies to secure the City's infrastructure from the effects of climate change". A New York City Panel on Climate Change (NPCC), modeled after the United Nations' Intergovernmental Panel on Climate Change and consisting of 15 experts in climate science, economics, law, and other fields, was formed to provide the Adaptation Task Force with "climate-change projections; help … identify at-risk infrastructure; develop adaptation strategies and draft guidelines for design of new structures".

NPCC's report "Climate Change Adaptation in New York City: Building a Risk Management Response" was published by the New York Academy of Sciences in 2010 (NPCC 2010). This built on and updated the earlier MEC investigations by the same lead scientists, focusing specifically on the city. Expected changes in climate quantities such as temperature and precipitation were given based on the full range and the middle two-thirds of climate models that submitted results to the IPCC's Fourth Assessment Report (2007). The exception to this was the range for sea level, which was extended upward, to 30–140 cm by the 2080s, to include possible more rapid melting of ice sheets, with the upper bound taken to be the average ice sheet-melting rate during the last deglaciation. However, the risk for extreme storm surges of given height above sea level was assumed to remain the same in the absence of convincing historical observations or model simulations of a trend; as seen above, this may be proving overoptimistic. Several categories of extreme events were considered: for example, both severe drought and heavy precipitation were likely to become more common. Likely impacts of these climate changes on infrastructure were listed in some detail, grouped by category of climate change (temperature, precipitation, sea level) and by infrastructure sector (communication, energy, transportation, water and waste). The report advocated the concept of Flexible Adaptation Pathways that would improve the resilience of infrastructure incrementally, tied to current maintenance cycles, while monitoring local and global climate changes and impacts to determine whether more drastic (and costly) adjustments are required (Rosenzweig et al. 2011).

The city's Green Codes Task Force (2010, http://www.nyc.gov/html/gbee/html/codes/proposals.shtml) suggested changes to city law to encourage and facilitate adaptation based on the findings of the NPCC report (Sussman et al. 2010). Examples included creating a new map of flood zones to use in city planning that takes expected sea level rise into account; requiring safe storage of toxic materials in low-lying areas so that they do not spill during floods; and requiring environmental impact statements for proposed city projects to discuss the expected impact of climate change on the project. Many of these proposals were enacted in 2010–2011 (http://www.c40cities.org/c40cities/new-york/city_case_studies/green-codes-task-force).

More ambitious programs for adaptation were presented at a 2-day conference held in 2009 by the American Society of Civil Engineers (ASCE) titled "Against the Deluge: Storm Surge Barriers to Protect New York City", which took heed of the flooding of parts of New Orleans by Hurricane Katrina in 2005 (Hill et al. 2013). This reported on hydrodynamic modeling of the feasibility and impacts of barriers that could be raised to keep an impending storm surge out of New York harbor carried out at Stony Brook University with funding from New York state's Sea Grant Program and the New York City Department of Environmental Protection (Bowman et al. 2005; Colle et al. 2008). The inability of the city's infrastructure to withstand hurricane storm surges even before considering sea level rise has been long appreciated (Kussman 1957; Mather et al. 1967). Several designs for different configurations of barriers were also presented. It was noted that regulatory and financial obstacles to such barriers were historically only overcome in other cities after a damaging flood made it possible to get wide public and institutional support. Accordingly, ASCE held a follow-up conference on the topic on April 2013 to explore "potential solutions to reduce the impact of storm surge and flooding caused by Sandy".

14.4 Climate Change Adaptation Research Case Studies

14.4.1 A Bridge Rating System for Scour Hazard Under Sea Level Rise

Scour as a result of flooding, resulting in failure of the foundation, is the leading mode of bridge failure nationally. For bridges over waterways, the 100- and 500-year storm recurrence periods serve as the key design criteria to design and protect bridges against scour according to Federal Highway Administration specifications;

the design storms are based on Federal Emergency Management Administration flood maps that do not currently include any provision for sea level rise. A recent civil engineering doctoral dissertation at the City College of New York (CCNY) (Shields 2012) modeled scour during 100- and 500-year flood events for a sample coastal bridges in the NYC metropolitan area, using both present and high-end projected 2080s sea level (+140 cm, based on the NPCC). A revision to the existing New York State Department of Transportation (NYSDOT) prioritization system for bridge rehabilitation was proposed to take into account vulnerability under sea level rise, along with other factors such as bridge age and the availability of alternative routes. This research program was undertaken with the cooperation of NYSDOT and the Port Authority of New York and New Jersey, which provided bridge plans used in the modeling study. However, no concrete changes in bridge maintenance standards by state and city regulators have yet been made. Follow-up research at CCNY is aimed at estimating regional changes in heavy precipitation extremes, which affect river runoff extremes and hence scour potential for interior bridges that span rivers.

14.4.2 Improving Models of Evapotranspiration from the New York City Water Supply Area

The New York City Department of Environmental Protection (DEP) has been hosting postdoctoral fellows from the City University of New York (CUNY), which includes CCNY, for several years. These scientists have been helping DEP to research climate change impacts on water quantity and quality by developing hydrological models and measurements (Rosenzweig et al. 2007; Matonse et al. 2011; Zion et al. 2011). Extending this collaboration, CCNY and DEP scientists, funded by NASA Earth Science Division's Applied Sciences Program, are working to use thermal, microwave, and other remote sensing data to infer soil moisture and evapotranspiration spatiotemporal patterns from the watersheds under drought conditions and compare these with those in the watershed hydrology models DEP uses for scenario planning and operational management. The increase in evapotranspiration with warming potentially threatens New York City's water supply in future decades, particularly in the summer and early fall months, but there have not been any measurements of evapotranspiration in the city watersheds for calibrating and validating the models being used by DEP to project risks to the water supply. Preliminary results comparing modeled evapotranspiration with that derived from MODIS satellite imagery (Mu et al. 2011; Ryu et al. 2011) show some discrepancies between remotely sensed and modeled evapotranspiration (Fig. 14.4). These can be understood as reflecting systematic bias in the model formulation, such as too little water storage in the soil (Krakauer et al. 2012). Correcting such biases should enable more realistic predictions of the impact of climate change on water. These predictions could, in turn, affect the reservoir operation rules and watershed management strategies that NYCDEP adopts in order to supply sufficient water

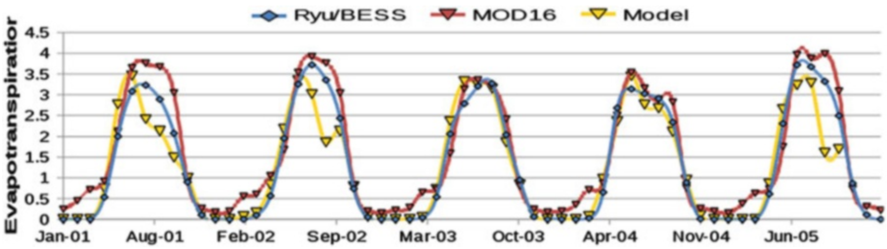


Fig. 14.4 Evapotranspiration (mm/day) for one of the New York City water supply watersheds as simulated with NYCDEP's current operational model and as estimated from remote sensing using two algorithms (MOD16, Mu et al. 2011 and BESS, Ryu et al. 2011). The modeled evapotranspiration frequently appears too low in late summer

while maintaining turbidity standards by controlling eutrophication and sediment loading in its watersheds, which is necessary in order to avoid a costly requirement for filtration (Bryant et al. 2008).

14.5 Conclusions

Solecki (2012) notes that New York City's climate change adaptation trajectory is unusual among global cities in that it has the technical resources to commission science, engineering, and policy research specific to its needs. Through projects such as those discussed here, New York City is leveraging its human capital to make better use of current facilities and regulatory frameworks, providing a potential model for other jurisdictions. National and global city forums provide one way to share the lessons learned with smaller cities that do not have such resources (Rosenzweig et al. 2010).

The widespread devastation resulting from Hurricane Sandy may cause stakeholders' perception of needed research to shift to problems having more immediate applications—for example, more could be done for local armoring (Bolonkin 2007) or relocation of vital infrastructure links such as electric transformers. Increasing population and development, institutional inertia, and tight budgets have all slowed work toward improving preparedness in New York City (as in many other cities). A truly long-term perspective that takes into account the possibility of tens of meters of sea level rise if greenhouse gas concentrations do not drop from their current levels (Hansen et al. 2008; Foster and Rohling 2013) currently seems beyond the ambit of the municipal administration. To use the terminology of Kates et al. (2012), New York City will eventually move from incremental to transformational adaptation.

The challenge of adaptation to climate change may be viewed in terms of overcoming barriers in understanding, planning, and management (Moser and Ekstrom 2010). From this perspective, New York City has achieved at least provisional understanding of many climate challenges, as synthesized in the NPCC (2010) report. As for planning and management, some options have been presented, but the broad range of stakeholders that need to be engaged in the process of selecting, monitoring, and evaluating options for the more far-ranging of the needed adaptation strategies have not yet weighed in. These stakeholders include, first and foremost, New York City voters, taxpayers, and ratepayers. Outreach to a broad cross-section of New York City residents could occur through public comment opportunities, through local organs such as the community boards (Hum 2010), and through nonprofit and community groups such as those who manage and advocate for community gardens (Smith and Kurtz 2003; Eizenberg 2012). With a successor to Mayor Bloomberg to be elected in November 2013, the type of future political leadership for climate adaptation and the degree to which it can engage not only the research community and city agencies but a broad array of stakeholders remains to be seen.

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Chapter 15
Funding of Geosciences: Coordinating National and International Resources

Bente Lilja Bye and Kathleen S. Fontaine

As recently as 2010, the international scientific community, through the ICSU, identified five Grand Challenges that, if addressed in the next decade, will deliver knowledge to enable sustainable development, poverty eradication, and environmental protection in the face of global change (ICSU 2010). The five challenges for global sustainability research are: forecasting, observing, confining, responding, and innovating. These challenges were developed, according to the ICSU document, using criteria that examined broad scientific importance, opportunities for global coordination, relevance to decision makers, and leveraging of existing or upcoming breakthroughs. The ICSU document goes on to discuss a fifth criterion, whether support for funding exists in the broader community.

The fact that ICSU and others have identified such challenges is not new. The Rio +20 United Nations Conference on Sustainable Development in Brazil in 2012 included a call for continued action to eradicate poverty and work towards achieving the Millennium Development Goals (United Nations 2012). The World Summit on Sustainable Development made similar statements in 2002, regarding the areas of water, energy, health, agriculture, and biodiversity (United Nations 2002). The 1992 Rio Earth Summit on Sustainability highlighted poverty, funding, and other areas for renewed or increased focus (United Nations 1992). The list goes on, and the issues continue (Fig. 15.1).

Reading through the documentation, it is clear that there are needs that must be continually addressed in order to meet the ongoing issues of sustainability on our planet. In a world where the population grows at an estimated rate of 200,000 people per day while resources continue to dwindle, it is indeed appropriate to keep the clarion call of sustainability alive (World Bank n.d.).

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Fig. 15.1 Planet Earth faces many challenges. The Blue Marble by NASA

A further read of these and other documents highlights another constant drumbeat of the need for resources—funding, collaboration, data, observations, equipment, policies, and other contributions that make each of these challenges achievable. Over time, it has also become clear that no one government, NGO, international organization, agency, or other entity can do everything. The challenge, therefore, becomes how to use research and observations to benefit society and achieve the main sustainability goals laid out over time. Citing the earlier ICSU work, in fact, Keenan, Cutler, Marks, Meylan, Smith, and Koivisto emphasized the need for increased coordination and a more global slant to environmental research for societal benefit (Keenan et al. 2012).

As this problem is not a new one, the goal of this chapter is to take a look at a more fundamental aspect of such coordination, namely the landscape of funding and collaboration activities in the Earth observations world, and to offer some practical, candidate approaches for achieving results. First, we provide an overview of the role that Earth observations might play in such collaborations, including the role of one international organization in particular, the Group on Earth Observations (GEO). Next, we discuss the actors, timescales, and instruments that make up the research system as a whole, highlighting what has worked in the past. We discuss in more depth the efforts of the GEO to bring Earth observations, science, technology, and resources together for societal benefit. Finally, we propose possible ways forward.

15.1 The Role of Earth Observations

Earth observations are data obtained about some aspect of the Earth. Earth observations may be in the form of pictures, computer models, movies, printed pages of numbers, or any other format deemed useful to some audience (Wigbels et al. 2008). These data may come from satellites, buoys, ground sensors, aircraft sensors, or any other instrument that measures some parameter. The role of Earth observations to benefit one's everyday life has been solidified over time through commonplace products such as weather forecasts, flood height, air quality indices, and pollen counts. What may be less well known to the average person is the way these technologies can benefit society more broadly. NASA's SERVIR program provides one example of the broader value and power of using Earth observations for societal benefit, and of the power of cooperating and sharing the resource load.

Begun in 2004, SERVIR sought to use expertise and resources from NASA, USAID, World Bank, and the Central Commission for Environment and Development to establish local capability in the areas of weather, disasters, and agriculture (NASA 2011). Visiting SERVIR staff began by teaching a local group of scientists and technicians to collect and interpret data from a variety of sources. As time went on, the local group became more and more self-sufficient, eventually taking over all aspects of the program at their local node. SERVIR nodes address local aspects of biodiversity, disasters, health, climate, water, and weather. Each of these plays a key role in the area's ability to adopt sustainable practices, and help achieve the desired outcome of reducing poverty.

It is not just the collection and manipulation of these data that are important, however. Sharing relevant data products and services in as full and open a manner as possible helps researchers across many disciplines and many countries solve problems unique to their area. Sharing also helps with the allocation of scarce research and development funding but freeing up money that might otherwise have been used to buy data. Access to data and open data policies through an agreed set of Data Sharing Principles are just two of the key objectives of an intergovernmental organization known as the Group on Earth Observations, or GEO.

15.2 The Group on Earth Observations

A recommendation of the 2002 Johannesburg Summit, and an offshoot of the G-8 Glen Eagles declaration, GEO was established to produce a "coordinated, comprehensive, and sustained system of systems" (G8 Nations 2005; Group on Earth

Fig. 15.2 The Global Earth Observations System of Systems and its nine societal benefit areas

Observations 2005a). The Global Earth Observations System of Systems (GEOSS) is the goal of nearly 90 governments—to make Earth observations data, products, and services easy to find, easy to share, and easy to use. Once completed, the Global Earth Observing System will contribute substantially to addressing many of the challenges levied over the years, and specifically to the ICSU Observations challenge (Fig. 15.2).

The Global Earth Observation System of Systems will provide decision-support tools to a wide variety of users. As with the Internet, GEOSS will be a global and flexible network of content providers allowing decision makers to access an extraordinary range of information at their desk. The GEO Work Plan provides the agreed framework for implementing the GEOSS 10-Year Implementation Plan from 2005 to 2015 (Group on Earth Observations 2005b). The Work Plan is a living document that is updated annually, and can be used to support efforts for international funding arrangements.

The Work Plan tasks are funded through voluntary contributions in kind, in cash, or in other resources. While the voluntary nature of GEO has definite advantages in the environmental governance arena, the lack of dedicated funding to support specific science and technology activities in support of GEOSS is one of the most important obstacles to engaging the science and technology communities in its implementation. This problem can be addressed to some extent by establishing explicit linkages between research and development programs funded by GEO Members and Participating Organizations and GEOSS. Funding concerns can also be addressed by going to member nations of GEO, or other funding organizations with specific requests.

In appropriate funding programs, these requests may take the form of requiring explanations of how projects to be funded will interface with GEOSS and ensuring that demonstrating significant relevance for GEOSS is viewed as an asset of these proposals, requiring registration of Earth observing systems developed in these projects, or stipulating that data and products must adhere to the GEOSS Data Sharing Principles.

15.3 The Research and Innovation System

In order to better understand the challenges connected to the funding of an initiative like GEOSS let us take a closer look at the whole research and innovation system.

The research and innovation system can be divided into three different levels: the political, strategic and performing level. Each nation has its own specific set of interactions between all three levels, the organization structure, decision-making processes, developing policies, funding models etc. (Fig. 15.3).

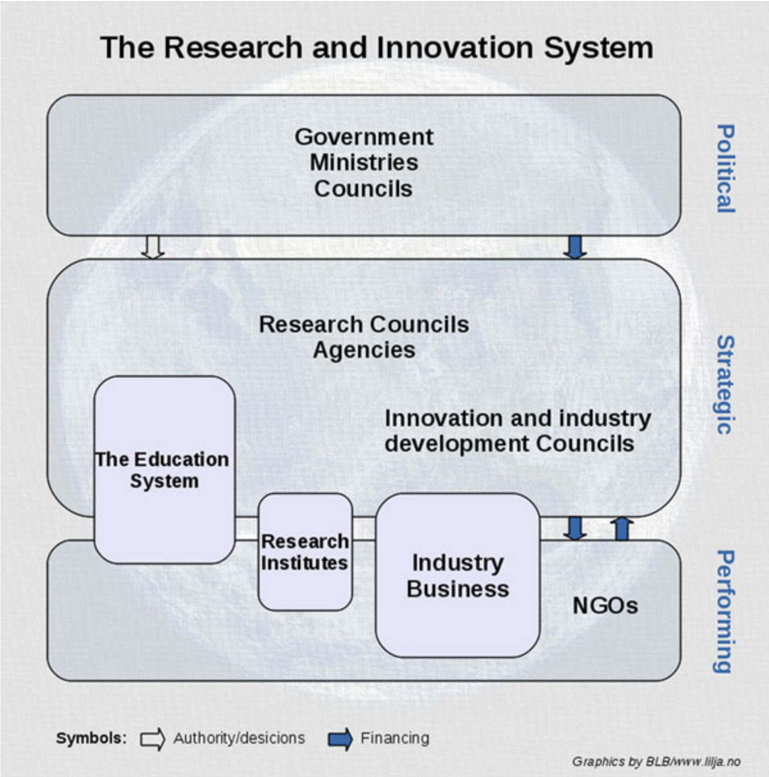


Fig. 15.3 The research and innovation system can be divided into three levels—the political, the strategic, and the performing level. The many actors interact in various ways depending on national structures and procedures

Research systems are inhabited by a number of actors. On the political level we find the ministries. Research is planned and financed by ministries, which are most often Ministries of Science or Education or Culture. The important Ministry in terms of funding is often the Ministry of Finance, which decides on the overall research budget. As research is often linked with education and innovation issues, Ministries of Education, Economic Affairs, Trade, Industry, or Technology are often mentioned as other responsible ministries.

While the funding is most commonly provided via the ministries of research and science etc., the decisive policy-making level is not necessarily an individual ministry, but a council. A number of countries have developed a coordinating council, often called "Research and Development Council" or "Science and Technology Policy Council". These structures have a coordinating function among ministries responsible for research policies.

The third actor is composed of administrative organizations: an array of funding and implementing organizations, agencies, or even dedicated ministerial departments can be found in many countries. However some have more, others have less of them. The organizations are in general depending directly on a specific ministry or they are kept at arms length. In several countries, each research policy making Ministry has at least one implementing organization, meaning that it distributes the funding from the ministry and implements the program or project directly or again, with the help of a third organization. This leads to a rather heterogeneous implementation and the more organizations and institutions are involved, the greater the demand for coordination. Consolidation or bundling of the various organizations is therefore a task to be dealt with in several countries.

A fourth actor that is similarly important is the policy advisory or consulting actor. The number of agents in this group seems to be even broader and more heterogeneous than the former one. While the learned societies, research councils, and academy of sciences among others are the well-known and well-established lobbying groups that voice their interests in the policy-making process, they equally provide advice.

A fifth actor is associated with NGOs and stakeholder organizations. These may, for instance, be environmental organizations with a strong popular support, industry branch organizations and various non-governmental funding organizations and foundations. These organizations may play an important political role, as they strive to influence policy makers.

Finally as a sixth actor, there are private companies that fund or perform R&D or, which by commissioning relevant research from research organizations or by acquiring spin off companies that have grown out of university research, may influence R&D investment priorities in a profound way. Companies may also contribute to the relevant knowledge base through incremental innovation and by providing methods and instruments that can be used by researchers and experts elsewhere.

All of these actors belong to what we call the research and innovation policy system, where there may be a close interaction between organizations and the people working in them. There may also be mobility of personnel, leading to competence transfer, common learning and political influence.

And finally we have the seventh actor, the research performers. Among the most prominent we find the universities and public research institutes, although some large multinational companies may have the research facilities needed to contribute in a significant manner.

Although comprised by the same fundamental components, the research and innovation policy system in each country will vary a lot (ERAWATCH n.d.). The countries have a different historical and cultural background, various capabilities in terms of research and education, different industrial structures and trajectories, and different approaches to welfare and social policies. The political culture may also differ, which leads to different approaches with respect to collaboration and governance, as well how struggles for power and influence play out. Indeed, there is a lot of variation inside the national systems as regards "belief systems"—i.e. coherent narratives about how the world is and should be—and policy practice.

It is within the framework of these research and innovation systems that resources for GEOSS have been and will continue to be mobilized.

15.4 Funding Models and the Funding Cycle

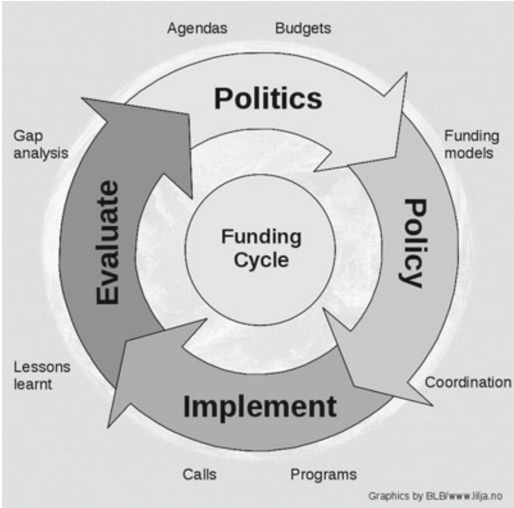
Based on the cultural, economic and political context, many different funding models are employed in multinational frameworks for research and innovation collaborations (OECD 2012). When defining a funding model for the collaboration, it is pivotal to take into account the different processes involved in creating new knowledge such as described in the research and innovation system. A typical challenge for international collaborations when it comes to finding the optimal funding model, is to strike the right balance between core and project funding. Sufficient core funding is often difficult to obtain while in-kind and project funding make long-term planning hard. Examples of funding models are "real common pot", "virtual common pot", "mixed mode pot" and "no common pot," all of which have context-dependent advantages and limitations.

Another issue that needs to be taken into account is the different phases of the funding mechanisms for research and innovation.

Policies are being conceived, born and executed. At any point of time there will be development of new politics, policies and implementation tools and finally performance of research. For instance, at the end of research programs one typically summarizes the results and looks at what remains to be done as well as making notes of new ideas that have been born during the program period. This is then given as input to the development of new policies and so on (Fig. 15.4).

When a new organization is created and becoming a part of the research and innovation system, the mobilization of resources is taking place in all the phases of a funding cycle more or less simultaneously. Firstly through the coordination of already available resources, then applying for new money in existing research programs and finally the longer-term perspective contributing to the development of new policies that incorporate the needs and activities of this new member of the research system.

Fig. 15.4 The funding cycle of research systems



In order to build alliances and get continued funding, you need policy entrepreneurs that know how to handle the cultural differences and who takes part in cross-border networks. When adding an extra international level with international organizations and multinational companies who have their own beliefs and ways of doing things, things get really complicated. In any strategy for developing international research initiatives aimed at societal, environmental and global challenges such as is the case with GEO and GEOSS, one has to take all of this complexity into consideration.

15.5 Funding GEOSS

15.5.1 Catalyzing Resources for GEOSS

Part of the Work Plan for GEOSS has been a set of components designed to discover and catalyze resources in support of the GEO objectives. The initial work included developing a list of funding organizations whose goal is to fund projects and research that would enable completion of GEOSS Work Plan tasks, and then to develop a document that highlighted the science that could be conducted should those agencies contribute (Fellous and Bequignon 2010). Organizations such as the International Group of Funding Agencies for Global Change Research (IGFA), and their associated organization of the Belmont Forum, the Bill and Melinda Gates Foundation, and others are excellent potential sources of funding. The key word is, of course, *potential*, because such funding organizations are no different from government agencies in that they must see value before they assign resources. So how does one describe the value of the work of GEO?

Value is demonstrated partly through what has been accomplished, and partly through what has been identified as missing. To date, GEO has provided the platform for three international observation efforts to take shape that hope to change the landscape in the areas of agriculture, global forest cover, and biodiversity. These nascent organizations began as tasks in the Work Plan, which were championed by a small group of dedicated individuals. Over time, more GEO members saw the value of participating, and began to commit increasing amounts of resources to the personnel, research, development, and organizational aspects of each observing system. Successes such as these form a key part of the argument as to why funding organizations of any kind should contribute to GEO.

To identify what is missing, the next portion of the work included doing a gap analysis of the science and technology needs across the entire Work Plan. This was done through a combination of group activity and task survey. The goal of the exercise was to identify those areas of the Work Plan where specific, quantifiable gaps existed such that funding agencies with an interest in the topic could decide how to participate. One area of interest identified early was the need for more information on the global water cycle, and for more local efforts at determining water availability using Earth observations. For example, some areas of the African continent experience difficulties with water availability far downstream of the source (generally a mountain with a large snow pack). Access to Earth observations data and models regarding the location of the water, the timing of the snow melt, or the possibility of rain can give area farmers a better idea of where, when, and what to plant.

The next step towards funding involved bringing the funding organizations together, discussing the gaps and opportunities, and allowing conversations to flow from there. This effort is currently undergoing a phase where the test case of water issues being used to refine the process. An open forum is forming which will bring interested parties from around the world together in hopes of filling some of the critical resource gaps, as well as further drawing the interest of the science and technology communities.

15.5.2 The GEO Science and Technology Roadmap

In a related activity, GEO's former Science and Technology Committee developed a roadmap to ensure that GEO had access to scientific and technological advice in support of its Work Plan (GEO Science and Technology Committee 2009). Part of the roadmap includes identifying processes for funding research and development efforts in the societal benefit areas. As mentioned earlier, funding processes exist at many levels; but managing the complexity is a challenge. The key to success is building upon existing projects, utilizing all available processes to bring projects and funding sources together.

Other parts of the Roadmap concern sharing information about GEO and its accomplishments, organizing sessions at scientific conferences to discuss the ways in which Earth observations have been used to develop decision support tools, and encouraging GEO members to leverage the cooperative nature of GEO in their national funding instruments.

A major challenge to both the task and the Roadmap has been the difference between the nature of GEO and the nature of science and technology research and development. As mentioned above, national research funding tends to concentrate on those aspects of the agency mission or national need deemed most urgent. This focus is as it should be, with national needs being funded by national organizations. Increasingly, however, the value of international cooperation has become apparent to the point where it is possible for some national efforts to be designed to address issues common to many parties. Leveraging the funding and common goals of many partners is the basis of the funding model of the Belmont Forum, and is the starting point for all activities in support of the GEO Work Plan.

Another challenge centers on the difference between "pure" research (for the sake of increasing knowledge), and "applied" research (for the sake of using that knowledge or result in a particular way). Pure research has a traditional funding model that may or may not apply to the applied research world, however GEO is centered squarely in the applications world. The Group on Earth Observations as an entity does not have the authority or ability to fund anything, but rather depends upon its member nations to provide resources in support of whatever is deemed beneficial for GEO. In terms of pure vs. applied science, the answer is generally that GEO is concerned more with applications than pure research—to a point. While it is true that one would have a difficult time performing applied research with no data (no pure research result), one might have the opportunity to identify a knowledge gap while doing applied research.

What seems like a difficult problem may, in the end, be resolved through better communication of the link between pure research and applied research—that in the world of Earth observations, the data gathered for one feeds into the processes of the other.

Best practices: Two examples of international funding models (box):

1. *Common pot – European Commission's 7th Framework Program (FP7)*
   FP7 is the short name for the Seventh Framework Programme for Research and Technological Development. This is the European Union's main instrument for funding research in Europe and it will run from 2007 to 2013. FP7 is also designed to respond to Europe's employment needs, competitiveness and quality of life. Important research and development projects are funded through Framework calls. The European Commission is an international body that manage the program.

2. *Virtual common pot: International Opportunities Fond (IOF)*
   The International Opportunities Fund is a joint funding call between the Belmont Forum and G8 Heads of Research Councils (G8HORCs) for approximately 20M Euros. The countries involved in this initiative, currently, are Australia, Brazil, Canada, France, Germany, India, Japan, Russia, South Africa, the United Kingdom, and the United States of America. Possibilities for collaboration for non-participatory countries and developing countries exist as well. The current International Opportunities Fund is aimed at supporting research in the areas of Coastal Vulnerability and Freshwater Security.

The EC FP7 program is an example of a funding model where both funds and responsibility for selection and execution is transfer across national boarders. IOF is an example of an international funding model where funds are internationally coordinated but executed within national research systems. The latter is a so-called virtual common pot funding model.

15.5.3 Practical Approaches to Funding Big Challenges

So, where are we in terms of leveraging funding choices at the national and international levels?

GEO is well prepared for participation in both national and international funding processes in terms of having prepared proof of value, gap analysis and a well defined Work Plan for implementing GEOSS. The basis for having constructive dialogs on funding, funding models and mechanisms is there.

To facilitating a continuous analytical process within the member countries and participating organizations of GEO, a methodology, or tool, was developed through the EC funded project called Egida—Coordinating Earth and Environmental Cross-Disciplinary Projects to Promote GEOSS. The methodology focus on national and regional levels and aim to coordinate national multi-disciplinary "System of Systems" where also national funding is being addressed as part of the method. It is worth mentioning that EC's FP7 program itself is an example of an international 'common pot' funding model, one of the options mentioned above. Another activity in Egida was the development of a suitable funding mechanism for GEO in Europe (Bye et al. 2012). The main outcome from this work is that we need a better understanding of what kind of barriers, such as legal, political, budgetary timelines, IPRs etc., have to be overcome to define an effective funding mechanism for the implementation of GEOSS. Another issue that needs further analysis is the implications of the highly multidisciplinary character of GEOSS.

In lieu of trying to address all the societal benefit areas covered by GEOSS, the GEO community appreciates the complexity these global challenges represent and decided to use a more practical and focused approach. As described above, global water cycle was early identified as a topic of interest for many.

This approach is supported by the conclusions from the work of OECDs STI working group in that the discussions on governance (funding being an element of that) of global challenges was typically too general and thus not so useful for practical implementation.

In August 2012 the small sized task force on funding global water cycle activities included in the GEOSS work plan thus started to work taking the following steps:

1. establish a small open task force consisting of both experts from the global water cycle community and people with expertise and interest in funding in the research and innovation system,
2. select a subset of activities from the tasks related to global water cycle in the GEOSS Work Plan,

3. nurture and initiate collaboration with the international network of funding agencies, focusing on agencies that already had demonstrated an interest in international funding. This dialog will address issues related to all phases of the funding cycle; politics (GEO has a Ministerial Conference every 5 years), policy development (defining the research and innovation agenda, formulation of calls etc.), using existing funding instruments (answering calls and coordinate existing resources) and provide input to the evaluation process.

The task force has two main goals: (a) to actually provide international funding for one or more of the selected activities and (b) to closely monitor the process taking notes of the various problems met on the way. In order to benefit the most from this heuristic approach it is considered equally important to make mistakes or encounter seemingly insurmountable obstacles as to succeed. A comparative study of this activity is under development.

Through a very concrete and limited in size task one aims at strengthening the relationship between the actors, in this case GEO and funding agencies in particular. Together they will define the process that will enable us to better manage global challenges of our time.

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Chapter 16
Big Benefit from Big Data: A Real-Time Data Product Creation and Distribution System

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The term *big data* describes the huge amount of data collected in today's world and indirectly refers to the challenges of managing and interpreting the data so it can become meaningful. Big data that is also dynamic and real-time, as is common with environmental data, presents a unique challenge, no matter what the specific field of study. If masses of raw data are to be transformed quickly into accessible and useful information, new software systems are needed.

As an important resource for real-time air quality information since 1997, the United States Environmental Protection Agency's (US EPA) AirNow program is embracing the challenges of using big data to inform the public about the quality of the air they breathe. Every hour, real-time data from over 2,500 monitoring sites is delivered by more than 130 environmental agencies across the United States, Canada, and parts of Mexico into the AirNow system. AirNow's Information Management System (IMS) is the key component that enables AirNow to keep up with such large amounts of constantly changing data and disseminate current information.

IMS provides an efficient and flexible way to automatically ingest and process air quality data and forecasts and to create information products that are understandable to the general public. Although the IMS framework was developed to manage US air quality data, it can easily be adapted for international users and for use in other scientific disciplines. IMS could manage data from earthquakes, volcanoes, fires, rocks, soils, rivers, and oceans just as easily as it manages air quality data.

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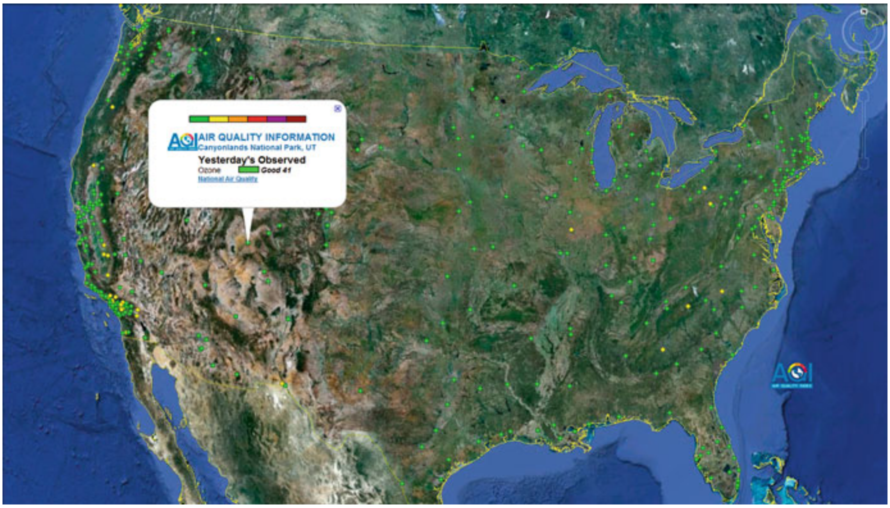

Fig. 16.1 Example of a KML file showing regional air quality information, generated automatically by IMS. Files like this are produced by IMS continuously for the US EPA's AirNow website www.airnow.gov

The ability to efficiently create, customize, distribute, and update thousands of public products in real time makes IMS especially useful for disseminating information that changes frequently. IMS distributes its workload across multiple servers, builds products as data arrives, and reuses existing data products to create new ones.

Another important feature of IMS is its flexible, modular nature. IMS comes with a built-in suite of applications that create maps, KML files (see Fig. 16.1), and other files, but custom add-ons can be developed and integrated into the system without requiring modifications to IMS itself. Servers can be added or removed as needed for jobs of different sizes, and new data sources can be easily incorporated and brought to new audiences. In addition, IMS was designed to facilitate support for multiple languages; versions already exist in English, Spanish, and Simplified Chinese.

16.1 History of IMS

Built for the US AirNow program (www.airnow.gov) in 2010, the current AirNow suite of software applications, which includes IMS, is a complete redesign that replaced the original, 10-year-old system. The current system was designed to improve the usability for non-software developers, make the system more adaptable to multiple data sources, and increase the speed at which a continuingly increasing amount of information can be disseminated to the public and other interested parties. The current system is also intended for easy adoption by environmental agencies worldwide as a tool for improving air quality data management and governance. The system's design is based on non-proprietary standards so that the software package can be easily shared.

Launched simultaneously in the United States and Shanghai, China, for the 2010 World Expo, the re-engineered system addresses other challenges besides its transferability to multiple agencies. The original system frequently required manual maintenance and the running of manual processes; the revamped system is more adaptable and rebuilds products automatically when data updates arrive. In addition, the original system's mapping software had a geographic extent limited to North America and did not have foreign language output capability; the new system allows for worldwide mapping and multi-lingual product outputs. Furthermore, the modular and scalable nature of the current system means easy customization and adaptation for new purposes, including new data input and output formats.

The AirNow program uses IMS to process and generate products using data from the network of air quality monitoring stations around the country, air quality forecast data from state and local air quality agencies, and satellite estimates of particulate matter concentrations. IMS receives more than 15,000 data points an hour from the observational network alone and distributes more than 500 files an hour.

16.2 Components and Process

IMS is a distributed system that consists of four core components—the IMS server(s), the IMS desktop User Interface (UI), the IMS database, and a suite of software applications for building standard data products (see Fig. 16.2). IMS servers are responsible for retrieving data from files or databases that have new or updated data, queuing products to be built or distributed, and running applications that build or distribute file products. The IMS UI is used to configure file product templates using a Wizard-style creation process. These templates are used by the IMS servers to build files. The UI also allows users to monitor the creation and distribution of files by the IMS server(s) with a dashboard and to configure system and server settings. The IMS database stores configuration information about the system, data sources, and products to be built (from one or more data sources or file products generated by IMS). IMS also includes a suite of applications to build common data products such as map images (JPG, PNG), animations (GIF), KML files for use in Google Earth and other Earth browsers, gridded data files (NetCDF), and text files (CSV).

This section describes how a file product is configured within IMS, built, and then distributed. First, the user sets up a file product template as follows:

1. The IMS UI (see Fig. 16.2b) is used to create file product templates using a Wizard-style creation process or manually using a dialog box similar to the Create New Program dialog box (see Modular and Extensible, below).
2. When using the Wizard, the user selects the type of file to build, which data source(s) the file uses, and where the file should be distributed. Each of these steps has additional options based on previous selections. If the user is creating the template manually, advanced options are available, such as using a custom application instead of a built-in IMS application.

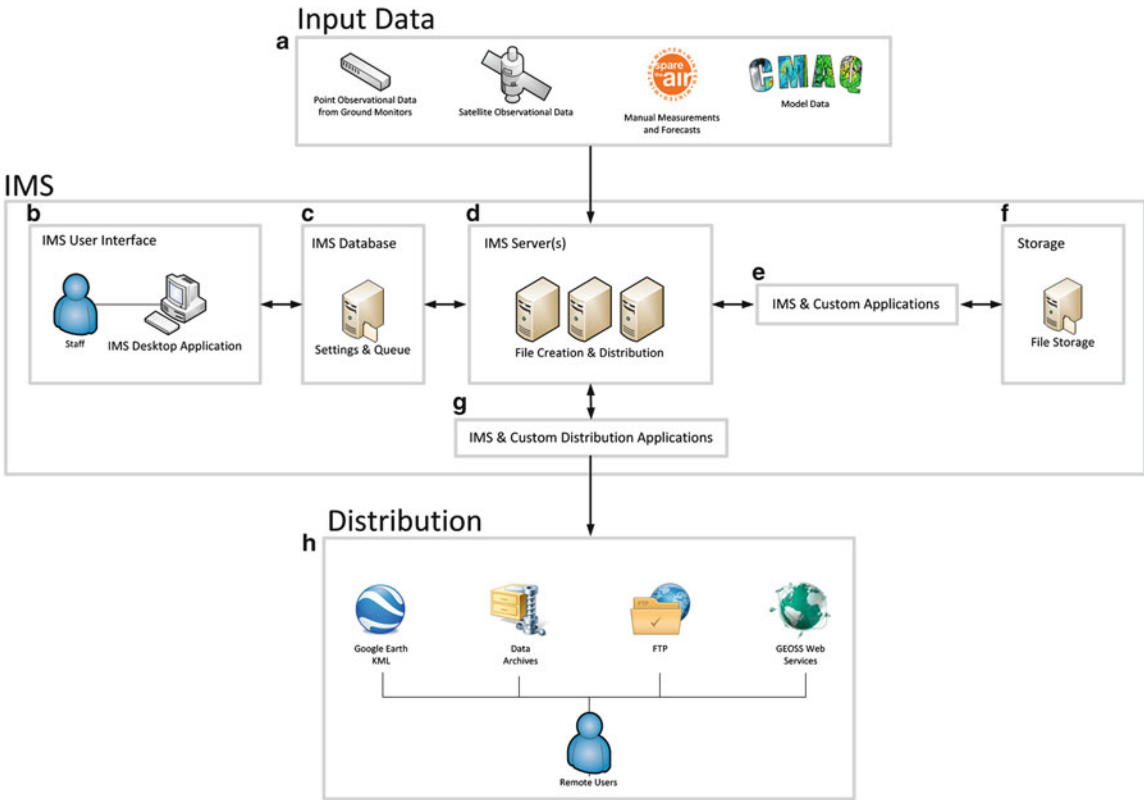

Fig. 16.2 IMS overview, showing (**a**) examples of input data sources; (**b**) the IMS desktop UI; (**c–g**) the IMS database and suite of software applications; and (**h**) examples of data services and feeds to which information products are distributed

3. When a file product template is created, a corresponding schedule is also set for IMS servers to begin checking whether data is available. See Frequent Updates in Near-Real Time (below) for more information on scheduling.
4. Users can configure the template so they will be notified via email if an error occurs while IMS is building or distributing a file.
5. This information is stored in the IMS database (see Fig. 16.2c).

After the template has set up the file product's configuration, the files are built and distributed as follows:

1. IMS servers (see Fig. 16.2d) continuously monitor data sources for new or updated data.
2. When new or updated data is available, an IMS server flags the affected files as *Ready to be Built* in the queue.
3. If a file type cannot be built directly from the data in the format provided by the data source, then the prerequisite files are queued to be built first. Files that require those prerequisites are flagged as *Waiting for Prerequisites*. See Frequent Updates in Near-Real Time (below) for details on the advantage of storing the intermediary files instead of having one application perform the entire process.
4. When a file product is ready to be built and a server is available to build it, an IMS server retrieves the file product template from the database and builds the file using the built-in IMS application or custom application configured in the template (see Fig. 16.2e).
5. Once the file is built, it is saved to the File Storage server where it waits to be distributed or reused to create another file (see Fig. 16.2f). The file is marked as *Finished* in the queue and any files that reuse it are marked as *Ready to be Built*.
6. If the file product template is configured for distribution, then the file is added to the Distribution queue in the database.
7. When a file enters the distribution queue, an IMS server distributes it using a built-in or custom application (see Fig. 16.2g) and marks it as *Distributed* when the process is complete.
8. If any errors occur while IMS is building or distributing the file—for instance, invalid credentials while sending a file to a remote system—IMS will check the configuration for users to be notified and send an email.

16.3 Important Features of IMS

The following sections highlight selected features of IMS that make it particularly well suited for generating useful products from big data sets quickly: (1) its ability to make frequent updates in near-real time; (2) its modular, extensible nature, which makes possible a wide range of customizations; (3) its scalability for handling increased activity; and (4) its ability to support different languages, thus facilitating international information sharing.

16.3.1 Frequent Updates in Near-Real Time

IMS reads data sources continuously to determine whether new or updated data are available, thus ensuring that the most current data are used for product creation. If new or updated data become available, products that use that data are immediately queued to be created or rebuilt. For example, the AirNow system creates air quality maps for specific regions. If a map displaying hourly data is scheduled to be built at the top of the hour, every hour, and the local air quality agency is late sending data to AirNow, IMS detects the change as soon as the datas arrive and automatically generates the map. This is different from a typical task scheduling system in which if the datas arrive late, either a blank map with no data will be created, or the map will not be created until the next hour.

IMS is also intelligent about data products that are a subset of a larger data product. For instance, to create a map of the west coast of the United States, IMS uses the west coast data from an existing national grid file.[1] By reusing preexisting data products or subsets of data products, IMS can build new products in a fraction of the time it takes a typical task scheduling system. This leads to quicker dissemination of information to the public and other interested parties.

To build the three air quality maps shown in Fig. 16.3, data must be retrieved from the database to create an Esri shapefile[2] that contains observational point data. The shapefile can be used to create the point map and grid file, which in turn can be used to create the contoured and combined maps. Instead of querying the database and creating each shapefile and grid file separately for each map, IMS builds the shapefile, stores it, and triggers the creation of both the point map and the grid file needed for the other two maps. The shapefile and the grid file are reused rather than re-created for each map, cutting the overall processing time by more than half. In most cases, the process is more complex; maps combining different data sets can generate ten intermediary data products between the raw data and the final map. Faster processing of the vast and changing data means faster communication to the public about the quality of the air they breathe.

16.3.2 Modular and Extensible

IMS can run most Windows command-line applications that do not require user interaction. It was designed so that software developers can create new applications in any programming language and incorporate them into IMS without having to change the underlying software and risk adding instability to the rest of the system. The *Create New Program* dialog box in the IMS UI allows users to easily set up the

[1] Converting individual data points to a gridded data file makes the data easier to display and is a preliminary step to creating map files. Algorithms are used to weigh and calculate values for the data points that are available near the fixed points of a regular, rectangular grid.

[2] Shapefile: a common file format for showing spatial data.

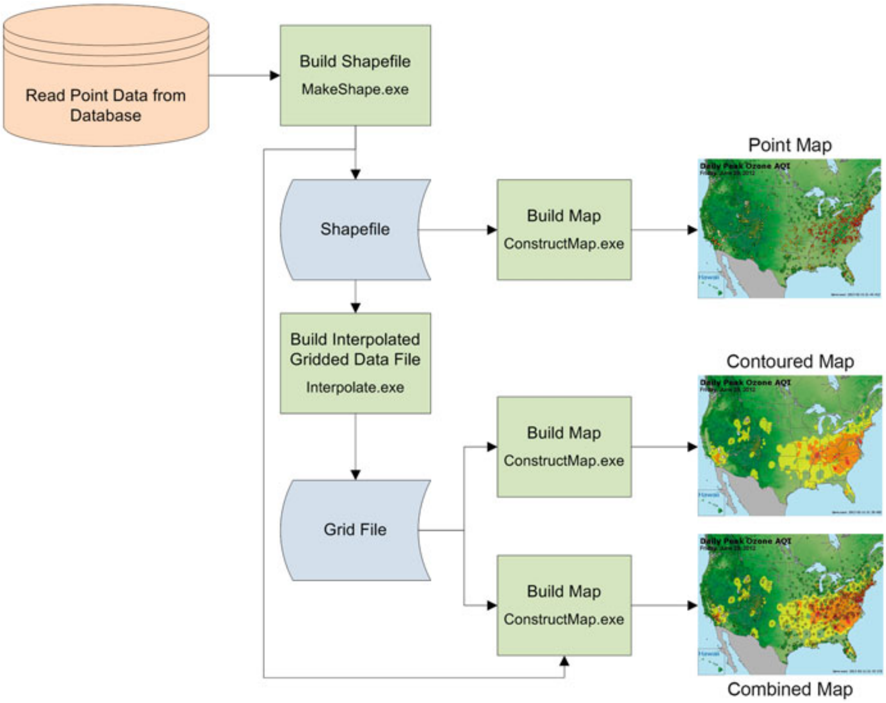

Fig. 16.3 IMS conserves overall processing time by reusing intermediary data products to create three maps from the same data. A typical task scheduling system would take more than 3 min to create all three maps. IMS takes less than half that time

custom applications for IMS to use (see Fig. 16.4). All that is required to add a program to IMS is to specify the IMS files the application will reuse as inputs, if any; the location of the application; and the command line arguments required to run the application. IMS can also be extended to interact with new data sources (data files, databases, etc.) and applications. Furthermore, the system is data agnostic: any type of data can be used, not only air quality data. For instance, a product could be built that overlays satellite spatial fire data on a map or KML file without any additional programming. Or an application could be written to take that same spatial fire data and combine it with spatial data created by a fire model to create a combined spatial data product.

16.3.3 Scalable

Every component of IMS can be run on a single server or across multiple servers, allowing the system to scale up or down as needed for projects of different size and complexity. Each file product can be built and/or distributed by all servers or

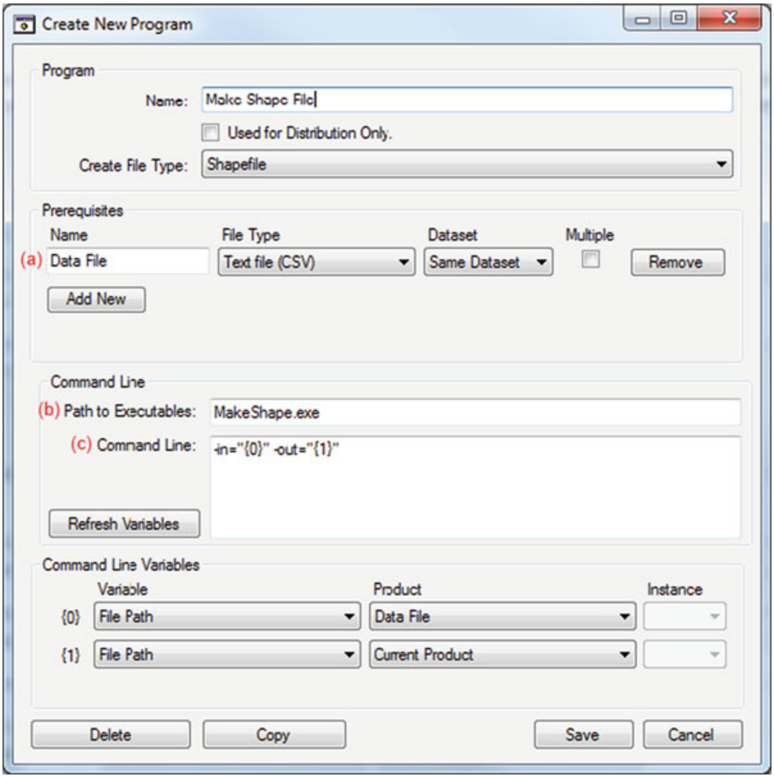

Fig. 16.4 IMS UI dialog for adding an application to be used by IMS by specifying (**a**) the required inputs; (**b**) the location of the application; and (**c**) the command line arguments required to run the application

configured to run on specific servers. If demand exceeds server capacity, another server can easily be added without rewriting any code. For example, three servers were cost-effective for AirNow's original needs, but a fourth, low-cost server was added to handle additional processing for a special project.

Instead of tying products to specific servers, IMS uses a queue stored in the database to prioritize the files that are ready to be built and evenly distributes the load across all IMS servers. The IMS servers remain at full capacity as long as there are files in the queue.[3] If an unusual situation temporarily increases demand on the servers (for example, if wildfires cause rapidly changing air quality conditions in a particular region), a dedicated server could be quickly added and then removed once capacity is back to normal. Furthermore, critical products, such as updated reports

[3] Through performance testing and research, we determined that it is most efficient for each core of a CPU to build a single file product at a time. IMS servers are thus set by default to simultaneously build as many files as they have CPU cores.

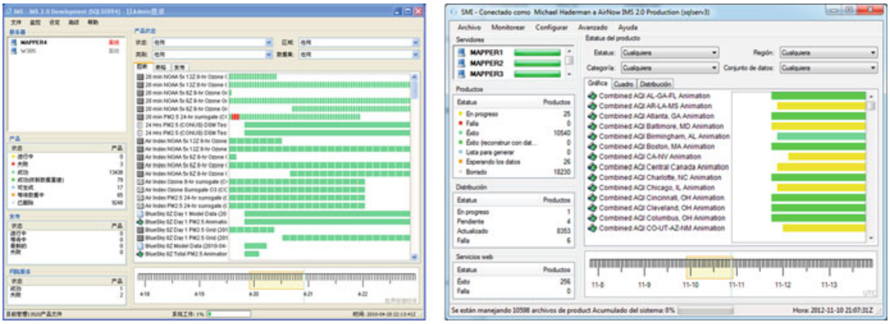

Fig. 16.5 Simplified Chinese and Spanish versions of the IMS user interface

for regions where wildfire smoke presents health concerns, can be prioritized to ensure that they are created or updated before lower-priority products. A file can be configured to use a specific server if, for instance, an application requires a license that is only on a single server.

This architecture has the added benefits that the database is the only single point of failure and any IMS server can be taken offline at any time without any other configuration being necessary. The rest of the servers in the cluster will continue creating products normally, but at a reduced capacity.

16.3.4 Multi-language Support

With the goal of promoting international data exchange through the AirNow-International (AirNow-I) program, IMS allows developers to easily add support for multiple languages. Languages are added to IMS by creating a new .NET language resource file that replaces English texts and phrases with their counterparts in the other language. Different languages, including those with different alphabets, can be displayed. IMS currently supports English, Simplified Chinese, and Spanish (see Fig. 16.5).

16.4 Examples of Custom IMS Add-Ons

The two examples described in this section demonstrate the capacity of IMS to expand into new areas. The AirNow-I installation in China and the automated fusion of ground-level observations with satellite observations illustrate IMS' adaptability to both a variety of agencies and projects that involve large data sets and complex, real-time processing. In each case, IMS provided the framework within which the desired software applications were added.

16.4.1 Shanghai Installation Example

Shanghai is the first city to run the AirNow-I software, which includes IMS. The Shanghai AirNow-I Initiative was a collaborative project between the EPA and the Shanghai Environmental Protection Bureau (SEPB) and its Monitoring Center (SEMC) to develop and install the AirNow-I system for the 2010 World Expo. Products from AirNow-I, for example, a regularly updated map, were used by the SEPB for environmental decision making as well as for alerting the public of potentially poor air quality on a special Expo website. The AirNow-I system created a stable data management infrastructure for the SEPB to develop new public reporting initiatives.

The AirNow-I installation in Shanghai is an excellent example of the adaptability of IMS to different agencies and purposes. Because the system is not tightly intertwined with a particular type of input or output, SEPB was able to use IMS with their particular data file formats and disseminate air quality information to the public in Chinese for the Expo. After creating a language file for Simplified Chinese, the SEPB was able to quickly implement IMS for data processing; no customizations were required.

16.4.2 AirNow Satellite Data Processor (ASDP) Example

The current AirNow monitoring network for $PM_{2.5}$ (fine particulate matter with a diameter less than 2.5 μm) has gaps, particularly in rural or mountainous areas, that leave many citizens without accurate air quality information. To improve coverage for sparsely monitored regions, satellite estimates available from the National Aeronautics and Space Administration (NASA) can be used. Combining, or fusing, the ground observations with satellite estimates of $PM_{2.5}$ can provide a more complete and accurate picture of national air quality conditions (see Fig. 16.6).

In 2012, the AirNow Satellite Data Processor (ASDP) was added to IMS to create additional maps and data products for AirNow. ASDP fuses surface $PM_{2.5}$ concentrations derived from NASA satellite data with surface $PM_{2.5}$ concentrations from AirNow to create new data products that show air quality information in monitor-sparse regions. ASDP uses the IMS framework (see Fig. 16.2) to create the fused data products through the following steps.

1. IMS checks to see whether satellite data is available. If data is not available, IMS continues checking on a regular basis until it can access the data.
2. IMS converts the satellite data into a gridded data file.
3. In parallel with the previous two steps, IMS checks to see whether the corresponding AirNow observation data is available and, once it has access, converts the data to a gridded file.

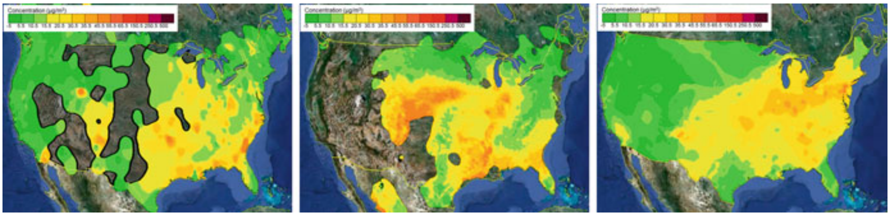

Fig. 16.6 Images showing US $PM_{2.5}$ measurements for June 8, 2011. Dark gray regions in the *left* and *center* maps show where data is unavailable (primarily in the western and central US). Coverage from AirNow ground-level monitoring is shown at *left*, satellite-estimated coverage is shown at *center*, and combined satellite-estimated and ground-level coverage is shown at *right*

4. Once both gridded data files have been created, the fused gridded data file is ready to be built using the ASDP fusion programs. If a server has capacity to build the fused gridded data file, the file is built immediately; otherwise, it is built as soon as a server is available.
5. Next, IMS uses other AirNow IMS applications to map the data from the newly created fused gridded file.
6. The new data products are then distributed by IMS to the ASDP project website (http://asdp.airnowtech.org) used by AirNow stakeholders.

ASDP not only illustrates the flexibility and modularity of IMS to process and display large fused particulate matter data sets now, but ASDP with IMS makes it possible to fuse other types of data such as model predictions, additional pollutants, and data collected from planned satellites in the future.

16.5 The Future of IMS

As other countries begin participating in the AirNow-I program, even greater amounts of global air quality data will become available. IMS will continue to enable decision makers and the general public to understand the meaning hidden within the raw data, even if common formats for inputs and outputs should change. Furthermore, IMS' adaptability for use by different agencies promotes regional and international data exchange and collaboration.

The modularity, extensibility, and scalability of IMS make it easily accessible and useful for multiple data types and a variety of scientific fields. Large and small groups can modify it to meet their specific needs for efficiently turning raw data into usable information. IMS has the potential to combine disparate data sets (such as official agency data, citizen data, modeling data, and satellite data) to create a comprehensive picture and improve situational awareness. Researchers can use IMS to process, merge, and distribute information from these diverse data sources to create integrated information products useful for making informed decisions.

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Chapter 17
Trusted Sources: The Role Scientific Societies Can Play in Informing Public Opinion on Climate Change

Christine W. McEntee

Much about public opinion on climate change science is not rational. When polled, a significant portion of the public expresses support and trust in science and scientists (National Science Board 2010). In addition, the overwhelming majority of scientists and the academies of science around the world have affirmed that climate change is real and that human activities are a significantly contributing factor (American Association for the Advancement of Science 2009; Anderegg et al. 2010). Yet, a significant number of Americans still express doubt, with only 54 % expressing belief that "global warming is caused mostly by human activities" (George Mason University Center for Climate Change Communication 2012).

17.1 Communicating Climate Change

Social science research shows an ideological divide between conservatives and liberals and between Democrats and Republicans, with conservatives and Republicans less likely to accept the scientific consensus and liberals and Democrats more likely to accept the scientific consensus (McCright and Dunlop 2011). Yet, examples exist where such a bifurcated choice presents only one clue as to how an individual or organization may view climate science. For example, the Catholic Church, which favors the conservative view on birth control and abortion, nevertheless is calling for action on global warming (Pontifical Academy of Sciences 2011). Former Representative Bob Inglis, who had an extremely high conservative voter rating when in office, has a long history of advocating for climate change action. Additional social science research provides further insight into the acceptance dynamics of climate change research. In Cultural Cognition of Scientific Consensus, the authors found that "individuals will more readily recall instances of experts taking the

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Table 17.1 Leadership summit on climate science communication participating societies

American Association for the Advancement of Science
American Chemical Society
American Geological Institute
American Geophysical Union
American Institute of Physics
American Meteorological Society
American Physical Society
American Society of Agronomy
American Society of Limnology and Oceanography
American Statistical Association
Arctic Research Consortium of the US
Center for Applied Research
Ecological Society of America
Geological Society of America
Society for Conservation Biology
Soil Science Society of America
The Oceanographic Society
University Corporation for Atmospheric Research

position that is consistent with their cultural predisposition than ones taking positions inconsistent with it" (Kahan et al. 2010, p. 4). The study also revealed that individuals tend to seek out information that agrees with their predispositions, rather than experts whose opinions may challenge them (Kahan et al. 2010). Such understanding of political affiliation and cultural predisposition helps to explain a policy environment where ideology can trump scientific consensus.

In 2011, AGU convened a Leadership Summit on Climate Science Communication. At the Summit, the presidents, executive directors, and senior public policy staff from 17 scientific organizations engaged with experts in the social sciences and practitioners and the agriculture, energy, and the military industries on the subject of effective communication of climate science (see Table 17.1). The discussions focused on three key issues: the environment of climate science communication; public understanding of climate change; and the perspectives of consumers of climate science-based information who work with specific audiences. Participants diagnosed previous challenges and failings and enumerated the key constituencies that need to be effectively engaged. They also identified the critical role played by cultural cognition—the influence of group values particularly around equality and authority, individualism, and community—and the perceptions of risk in forming public opinion. Barriers that scientists face in effectively communicating their findings to various stakeholder groups, including policy makers, were explored and considered.

Discussions emphasized the need for information tailored to specific audiences and collaborations among social scientists, practitioners, and professional communicators. Additionally, the attendees identified potential joint initiatives for taking these insights forward, for listening to different constituencies, for crafting and testing clear messages about the causes and consequences of climate change, and for disseminating these messages through multiple, credible sources. A clear takeaway was articulated by summit participant, Dr. Ed Maibach, professor and director

Table 17.2 Climate science messaging project participating schools

American Association for the Advancement of Science
American Chemical Society
American Geophysical Union
American Statistical Association
Ecological Society of America
Geological Society of America
American Society of Agronomy/Crop Science Society of America/Soil Science Society of America

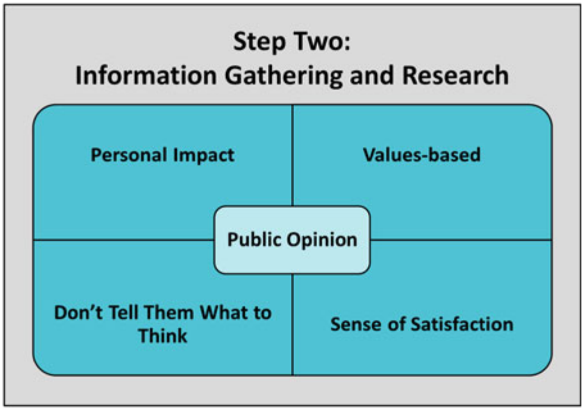

Fig. 17.1 Information gathering and research should be audience-centered

of the Center for Climate Change Communication at George Mason University: "Simple messages, repeated often, by a variety of trusted sources."

One project designed to begin addressing these issues is already underway. A climate-messaging project, spearheaded by AGU in collaboration with other scientific societies, began in early 2012. The project consists of a literature review of the current state of public opinion and understanding of climate science, qualitative and quantitative message research, and development of a message framework and tools that can be used by scientists and scientific societies to effectively communicate about climate science. This subgroup of societies shown in Table 17.2 has been conducting research to hone science messages about climate change science and to identify and explore ways that they, and their members, can improve the effectiveness of their communication with the public about climate change.

The data that has come from this effort has reinforced the findings of prior studies that illustrate the strong connection between cultural cognition and understanding and acceptance of the scientific consensus. As Fig. 17.1 illustrates, four additional insights were uncovered:

1. The impact of climate change on individuals' lives and livelihoods, such as devastation from extreme weather, along with how the media reports on climate change, has a much more significant influence on public opinion about climate change than scientific facts and studies.

2. Communications and messages that appeal to a person's values have great impact on the individual's opinion about climate science and climate change. Misinformation campaigns often pair narratives about the economic impacts of adaptation and mitigation strategies with values-centered messages of public accountability, small government, private property, and free enterprise. This creates a call-to-action for the public: Preserve your way of life by opposing climate change mitigation policies.
3. The public doesn't want to be told what to think. They want unbiased information from credible sources so they can make the best decisions for themselves, their families, and their communities. They take pride in, and derive a sense of empowerment and satisfaction from learning about an issue like climate change, and then being able to make a decision for themselves.
4. Scientists must find a way to show citizens how their research solves problems that are "top of mind" in the average household and aligns with key values that guide their everyday lives. Jobs, the economy, health care, public safety, and national security are more top of mind issues than climate change.

The research also reinforced earlier findings that scientists and scientific organizations are largely seen as the most trustworthy sources of information on climate change. However, a disconnect persists between scientists and their audiences. For example, the scientific usage of terms like "consensus," "projections," and "error" differs from nontechnical individuals' understanding of those terms (see Fig. 17.2). Furthermore, it is important not to overload individuals. More information and statistics, which can work well in communications with other scientists, do not necessarily increase understanding or acceptance of the scientific consensus. In fact, more facts and data can often backfire.

17.2 Investigate, Inform, Empower

Themes of investigate, inform, and empower emerged as a message framework from which scientists and scientific societies can develop more effective messaging about climate change and its impact on society. *Investigate* builds upon the public's trust in science and the approach that all scientists use to observe, experiment, analyze, and predict many aspects of our world. This approach has provided valid results and reliable information in the past and will continue to do so in the future. *Inform* reinforces the idea that policymakers and leaders in business, public health, and the military—as well as the general public—turn to scientists when they need information to make sound decisions regarding many issues and challenges. Scientists also actively engage in presenting reliable information that can inform policy decision-making. *Empower* draws the connection between scientists providing trusted and reliable information, and empowering policy makers and the public to make sound decisions and choices to protect the public from the impact of a changing climate. Scientific societies can work individually and collectively with

Terms that have different meanings for scientists and the public

Scientific term	Public meaning	Better choice
enhance	improve	intensify, increase
aerosol	spray can	tiny atmospheric particle
positive trend	good trend	upward trend
positive feedback	good response, praise	vicious cycle, self-reinforcing cycle
theory	hunch, speculation	scientific understanding
uncertainty	ignorance	range
error	mistake, wrong, incorrect	difference from exact true number
bias	distortion, political motive	offset from an observation
sign	indication, astrological sign	plus or minus sign
values	ethics, monetary value	numbers, quantity
manipulation	illicit tampering	scientific data processing
scheme	devious plot	systematic plan
anomaly	abnormal occurrence	change from long-term average

Fig. 17.2 Words connote different meanings for the public than they do for scientists as shown in this chart adapted from "Communicating the science of climate change" by Somerville and Hassol (2011, p. 51)

each other and key stakeholders to reframe the message about climate change. In "Communicating Climate Change: Why Frames Matter for Public Engagement", Matthew C. Nisbet provides important insight into how framing the message matters and how reframing could benefit public understanding of climate science and climate change. He advocates moving from communication as a process of transmission—that is, the scientific facts are assumed to speak for themselves with their relevance and policy significance interpreted by all audiences in similar ways—to applying and researching a framing typology for climate communication that trigger a new way of thinking and creating common ground and shared decision making. He identifies examples where framing has been both effective and not effective in changing public opinion about climate change. For example, framing the issue along religious and moral dimensions of climate change has led many religious leaders to make the connection between climate change and their faith. Alternatively, comparing distortion of the scientific consensus on climate change to other perceived distortions by governments or organizations for political means may appeal to liberal constituencies who accept the consensus on climate change. However, framing in this manner could be rejected by some segments of the population that view this as contrary to their partisan views and/or inside the beltway debate that isn't personally relevant (Nisbet 2009).

In addition to the climate-messaging project, scientific societies themselves can use framing to better tailor their communications about climate science and share this knowledge with their members, the public, and other key audiences. Societies also can learn lessons from the playbook successfully used by those who have been effective in seeding doubt about climate change, and how human activities contribute to it. They are consistent in their messages (they speak with one voice), they use framing for appealing to the anti-regulatory and anti-government values of their stakeholders, they are coordinated, and they are persistent. They even use scientific language, like "uncertainty" and "peer review" to publicly convey a sense of scientific legitimacy to their contrarian views.

Scientific societies, by their nature, have historically been more inwardly focused on advancing the science by supporting their members' research through their publications and meetings than on working together on broad-based public and policy communication efforts. Many don't have working relationships with other key stakeholders, such as public health groups, religious organizations, and others who can help frame messages reflecting the values of their communities. As a result, their effectiveness in communicating about climate science has been overshadowed by coordinated, consistent, and well framed messaging designed to portray doubt about the science and its impact. For scientific societies, framing and developing effective messages is just the beginning of a longer process. Exploring and implementing working coalitions around climate change communication that is values based, coordinated, consistent, and persistent would be a logical and needed next step.

When it comes to media coverage over the past several years, instances exist where climate science has been losing the war. It's not just about the level of scientific literacy in the population. According to a study in the journal, *Nature Climate Change*, people who are not that worried about the effects of global warming tend to have a slightly higher level of scientific knowledge than those who are worried (Kahan et al. 2012). Media interpretations or commentary can have significant impact on the public understanding of science, especially if credible science is somehow misrepresented. The recent increase in the number and intensity of severe weather events has recently drawn public attention to climate change. Although no one-on-one direct causal relationship exists between one specific weather event and climate change, climate change experts have been communicating that the world can expect more extremes of weather and weather-related events due to climate change. Yet headlines and words such as those used in the op-ed entitled "Leave It to The Global Warming Alarmists to 'Make Fake Lemonade' Out Of Hurricane Sandy." It stated: "Leave it to global warming alarmists to exploit the innocent victims of a human tragedy like Hurricane Sandy to spread the laughably false notion that global warming caused the storm…." (Taylor 2012). By presenting only a partial explanation of the current state of climate science knowledge, the reader could draw conclusions that the scientific consensus about climate science and its impacts is not universally accepted in the scientific community and is only being used for advancing certain policy actions.

17.3 Becoming Bilingual

Developing and implementing a message framework is just the beginning; it is not the end in what scientific societies and their members can do to better communicate to, and inform the public about the changing climate and its impact on public safety, national security, the economy, and public health. Scientists by their nature and study become proficient in communicating and discussing their science with other scientists. They are passionate and adept about applying the scientific method to understanding the natural world and explaining that method to an audience. However, cultural cognition studies tell us that values and cultural context play a greater role in a nonscientist's understanding of science than a multitude of facts and data. So do presentation styles with the scientists relishing data, graphs, bullets points, and error bars and the broader public favoring storytelling, compelling visuals, and humor for explaining scientific findings. Scientists can bridge the "communication gap" between their scientific world and the world of the broader public by becoming, in the words of Randy Olson (2009) "bilingual—to become conversant in your area of specialty in both languages" (pp. 171–172), academic communication and broad public communication.

Fortunately, scientists don't need to learn how to become "bilingual" on their own. There are a number of ways that scientists can improve their ability to communicate with a variety of audiences:

1. Be informed: By staying informed about new developments, particularly in the area of science policy, scientists can learn to target their message with "top of mind" issues and current events. AGU's science policy-related Twitter feed (@AGUSciPolicy) offers up-to-the-minute news on science policy-related happenings on Capitol Hill and elsewhere, and the Science Policy Alerts provide recipients with more detailed information on key strategic issues, including calls for action.
2. Access tools and resources: There are a multitude of tools and resources available online. For example, AGU has recently launched the Sharing Science website (http://sites.agu.org/sharingscience/). This portal provides users with a variety of tips, tools, and resources to help them reach out to policy makers, reporters, students, and the general public on a number of different topics. This site, which is designed to be a quick and easy reference, can be continually updated as new information becomes available, such as further knowledge related to successfully communicating about climate science, including suggestions on effective messaging by audience type.
3. Engage in training: Many of the scientific societies, along with science organizations like the National Science Foundation, offer training on effective science communication. For example, AGU offers annual training at our Fall Meeting and Science Policy Conference, as well as through an expanding online program. Topics covered include: Communicating with Congress; Using Social Media;

Informal Science Education in the Classroom; Communicating to the Media; and more. Each session is designed to equip attendees with the skills and resources needed to tailor their message to a specific audience in a way that the listener is likely to identify with and accept.

4. Learn what resonates with your audience: Gaining a deeper understanding of a particular audience's needs can also help scientists to better communicate. Many of the science societies sponsor congressional visit days designed to meet this goal. Education sessions in advance of the actual visits to Capitol Hill provide tips and techniques for effectively communicating with policymakers, and the visits themselves provide a guided type of practice.
5. Engage in outreach and education: By becoming regularly engaged in outreach activities, scientists can practice and hone their skills as communicators. AGU is working to build the engagement level within its membership through the Expert Outreach Network. The network is for AGU members who are interested in getting involved in anything from writing letters-to-the-editor to reaching out to policy leaders and talking to the media. It is open to those who have already received training or are interested in receiving training. These members work with AGU staff on a proactive and reactive basis to respond to trends and information that has surfaced in the news. As part of the planned expansion of the program, AGU will be helping members to connect with other key stakeholders in their community who are also concerned about climate change. This will allow them to combine their scientific expertise with a member of the community that understands the value set of their constituency—creating a powerful combination in climate science communications.
6. Consider a fellowship: Many scientific societies, including AGU, support more extensive training through sponsoring congressional and mass media fellowships and internships programs in their outreach departments. These programs allow members to broaden their skills and experience by working in Congressional offices, newsrooms and directly with society staff, gaining priceless hands-on practice.

17.4 Organizing for Greater Impact

Scientific societies, in addition to providing communication tools, training and resources to their members, need to reward, recognize, and defend those scientists who are educating the public and policy makers about climate science and its potential impact on society. Scientific career advancement is primarily linked to dissemination of research at meetings and in publications. By creating prestigious awards and recognition programs for scientists engaged in outreach, scientific societies can provide an incentive for scientists to engage in outreach and for it to be recognized as an essential element for career advancements. For example, AGU has implemented an annual climate communication prize. This prize, funded through the generous support of Nature's Own, recognizes an AGU member scientist who has been an excellent communicator of scientific science to a non-science audience. AGU is also implementing an Ambassador program. This program would recognize significant individual achievements in areas such as leadership and outreach, and would be on par with the prestige of AGU Fellowship.

Other avenues that scientific societies can explore include:

- development of a fact checker service for climate change information (e.g., FactCheck.org),
- collaboration with the climate science educational community to encourage and facilitate the inclusion of communications training in their curricula and to provide credence to outreach in tenure decisions, and
- development of a website for sharing information, having structured discourse, and making key resources available both to science and to other communicators and audiences.

Finally, scientific societies must staunchly defend their members engaged in climate science research who come under attack for their research. Scientific discovery and the scientific method are dependent upon the ability of scientists to question, challenge, and explore various alternatives before making conclusions. Taking this type of debate out of context and alleging that scientists are hiding crucial information or engaging in fraud and deception cannot be tolerated when there is no credible evidence to support such a claim. The East Anglia incident where scientists were falsely accused of inappropriately manipulating data to mislead the public about global warming, and the accusations and investigations into the work of Dr. Michael Mann and others were attempts to divert public attention and incite fear among the scientific community. Scientific societies need to make strong public statements against such unfounded accusations and provide tools and resources that can assist their members in responding to such attacks. AGU, in partnership with the Climate Science Legal Defense Fund, has been offering a series of legal webinars on such topics as what documents scientists must keep and disclose, an informational review of litigation involving Dr. Michael Mann, and science under legal inquiry. These and other types of efforts can help scientists be prepared and effectively address attacks on their scientific integrity.

Scientists and scientific societies have a significant role in educating and communicating the current consensus on climate change and its impacts. To be more effective than in the past, scientists and their societies need to create and frame messages that appeal to the values and belief systems of various audiences. Scientists and their scientific societies can use research from social, cognition and political science to reframe their messages in a way that resonates with the underlying values of various segments of society. The societies can use this research to create tools, resources and training that their members can tailor for communicating to policy makers and different segments of societies. And they can work together and with other stakeholders to incorporate these messages into a coordinated, consistent and persistent climate communication plan of action that can increase the public understanding and acceptance of climate change science and change public opinion about the impacts of climate change that society needs to address.

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